FORM PTO-1390 REV. 5-93	US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEYS DOCKET NUMBER
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		**P02,0085**
		U.S.APPLICATION NO. (if known, see 37 CFR 1.5) **10/070470**
INTERNATIONAL APPLICATION NO. **PCT/SE00/01714**	INTERNATIONAL FILING DATE **September 6, 2000**	PRIORITY DATE CLAIMED **September 9, 1999**

TITLE OF INVENTION: **"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR" (AS AMENDED)**

APPLICANT(S) FOR DO/EO/US: **CARL JOHAN HÖIJER and MARTIN OBEL**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ■ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. □ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ■ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ■ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. ■ A copy of International Application as filed (35 U.S.C. 371(c)(2))
   a. ■ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. □ has been transmitted by the International Bureau.
   c. □ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ■ A translation of the International Application into English (35 U.S.C. 371(c)(2).

7. ■ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. □ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. □ have been transmitted by the International Bureau.
   c. ■ have not been made; however, the time limit for making such amendments has NOT expired.
   d. □ have not been made and will not be made.

8. □ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. ■ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). **(UNSIGNED)**

10. □ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ■ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report)**.

12. □ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included.

13. ■ A FIRST preliminary amendment.
    □ A SECOND or SUBSEQUENT preliminary amendment.

14. ■ A substitute specification.

15. □ A change of power of attorney and/or address letter.

16. ■ Other items or information:
    a. ■ Submission of Informal Drawings; Request For Approval of Drawing Changes and **Priority Document 9903205-4**
    b. ■ **EXPRESS MAIL # EJ 552525064US**

U.S.APPLICATION NO. (if known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
10/070470	PCT/SE00/01714	P02,0085

17. ■ The following fees are submitted:	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): Neither international preliminary examination fee (37 C F R 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO and International Search Report not prepared by EPO or JPO $1040.00		
No international preliminary examination fee USPTO (37 C F.R. 1 482) not paid to USPTO but International Search Report prepared by the EPO or JPO $890.00		
International preliminary examination fee USPTO (37 C F.R. 1 482) not paid to USPTO but international search fee fee paid to USPTO (37 C F R 1 445(a)(2) $740 00		
International preliminary examination fee paid to USPTO (37 C F R 1 482) but all claimd did not satisfy provisions of PCT Article 33(1)-(4) $710.00		
International preliminary examination fee paid to USPTO (37 C.F R 1 482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100 00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F R 1.492(e)).	$	

Claims	Number Filed		Number Extra	Rate		
Total Claims	8	- 20 =		X $ 18.00	$	
Independent Claims	1	- 3 =		X $ 84.00	$	
Multiple Dependent Claims				$280.00 +	$	
TOTAL OF ABOVE CALCULATIONS =					$ 890.00	
Reduction by 1/2 for filing by small entity, if applicable Verified Small Entity statement must also be filed (Note 37 C.F.R. 1.9, 1.27, 1.28)					$	
SUBTOTAL =					$ 890.00	
Processing fee of $130 00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +					$	
TOTAL NATIONAL FEE =					$ 890.00	
Fee for recording the enclosed assignment (37 C F.R. 1 21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3 31). $40.00 per property **(see separate envelope)** +					$	
TOTAL FEES ENCLOSED =					$ 890.00	
					Amount to be refunded	$
					charged	$

a. ☐ A check in the amount of $__ to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **501519**. A duplicate copy of this sheet is enclosed.

d ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Schiff, Hardin & Waite
CUSTOMER NO. 26574
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606

Steven H. Noll
SIGNATURE

Steven H. Noll
NAME

28,982
Registration Number

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

AMENDMENT "A" PRIOR TO ACTION AND SUBMISSION OF SUBSTITUTE SPECIFICATION

APPLICANTS:	Höijer et al
ATTORNEY DOCKET NO.	P02,0085
INTERNATIONAL APPLICATION NO:	PCT/SE00/01714
INTERNATIONAL FILING DATE:	September 6, 2000
INVENTION:	"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR" (AS AMENDED)

Assistant Commissioner for Patents

Washington, D.C. 20231

Sir:

Applicants herewith amend the above-referenced PCT application as follows, and request entry of the Amendment prior to examination in the United States National Examination Phase.

IN THE TITLE:

Cancel the present title and substitute the following title therefor:

--"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR"--.

IN THE SPECIFICATION:

Please enter the substitute specification submitted herewith pursuant to 37 C.F.R. §1.125(b). A marked-up copy of the substitute specification showing all the changes is also enclosed. The substitute specification does not add any new matter.

IN THE DRAWINGS:

Please amend each of Figures 1, 2 and 4 as shown on the drawing copies attached to the Request for Approval of Drawing Changes, filed simultaneously herewith.

IN THE CLAIMS:

On page 11, cancel "*Claims*" and substitute:

--**WE CLAIM AS OUR INVENTION:**-- therefor.

Cancel claims 1-13 and substitute the following claims therefor:

14. A heart stimulator comprising:

a stimulation pulse generator adapted for interaction with an atrium and a ventricle of a heart for generating atrial stimulation pulses and ventricular stimulation pulses having an associated AV-interval;

an atrial sensor, adapted for interaction with said atrium, for sensing atrial signals therefrom;

an evoked response detector adapted for interaction with said ventricle for receiving ventricular signals, for detecting evoked response signals and including an averaging unit which forms an average amplitude value of respective evoked response signals during a predetermined time window of each cardiac cycle, said average amplitude values exhibiting a variability from cardiac cycle to cardiac cycle, and a comparator which compares said average amplitude value for each cardiac cycle with a predetermined variability limit, to generate a comparison result;

a determination unit connected to said evoked response detector and to said atrial sensor, which determines an incipient fusion AV-interval to be present if said comparison result indicates said variability limit was exceeded; and

a control unit connected to said determination unit and to said pulse generator for controlling timing of said ventricular pulses to produce a controlled AV-interval which is shorter than said incipient fusion AV-interval to maintain 100% stimulated beating of said heart.

15. A heart stimulator as claimed in claim 14 wherein said control unit modulates said AV-interval by a predetermined amount, to obtain a modulated AV-interval, and wherein said comparator compares respective average amplitude values for respective cardiac cycles wherein the modulated AV-interval was in effect, to said predetermined variability limit value.

16. A heart stimulator as claimed in claim 15 wherein said control unit regularly prolongs said AV-interval by said predetermined amount, to obtain said modulated AV-interval.

17. A heart stimulator as claimed in claim 14 wherein said evoked response detector samples and digitizes said evoked response signals for each heartbeat in a predetermined evoked response time window beginning at a predetermined time after delivery of a stimulation pulse from said pulse generator to said ventricle, thereby obtaining sampled amplitude values, and wherein said averaging unit forms said average amplitude value from said sampled amplitude values.

18. A heart stimulator as claimed in claim 17 wherein said evoked response detector samples and digitizes said evoked response signals with a sampling frequency and with a length of said evoked response time window so that approximately 20 of said sampled amplitude values are obtained within each evoked response time window.

19. A heart stimulator as claimed in claim 18 wherein said evoked response detector determines ADC level of said ventricular signals and subtracts said DC level from sampled amplitude value, before said averaging unit forms said average amplitude value.

20. A heart stimulator as claimed in claim 14 further comprising a respiration signal determining unit which determines a respiration signal associated with said patient, representing a respiration rate, from a predetermined number of said average amplitude values, and supplies said respiration signal to said determination unit, and wherein said determination unit generates said determination result dependent on said respiration signal.

21. A heart stimulator as claimed in claim 20 wherein said respiration signal determination unit determines said respiration signal from variations among a predetermined number of said average amplitude values.

IN THE ABSTRACT:

Please add the Abstract as set forth on separately numbered page 14 attached hereto.

REMARKS:

The present Amendment makes changes in the title, specification, drawings, claims, and adds an Abstract to conform the present PCT application to the requirements of United States patent practice. The cancellation of claims 1-13 in favor of the claims presented herein has been undertaken solely because the amount of bracketing and underlining necessary to conform the original claims to the requirements of 35 U.S.C. §112, second paragraph, would have been unduly burdensome and confusing. Accordingly, no change in the claim language between the present claims and the original claims has been made for the purpose of distinguishing any of the claims over the teachings of the prior art of record, and no change in the claim language therefore is intended by the Applicants as a surrender of any of the subject matter encompassed within the scope of the original claims.

Early consideration of the application is respectfully requested.

Submitted by,

Stan H. Noll (Reg. 28,982)

SCHIFF, HARDIN & WAITE
CUSTOMER NO. 26574
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606
Telephone: 312/258-5790
Attorneys for Applicants.

ABSTRACT OF THE DISCLOSURE

A heart stimulator has an atrial and ventricular pulse generator for producing atrial and ventricular stimulation pulses, an atrial sensor for sensing atrial signals and an evoked response detector for detecting the occurrence of incipient fusion beats from measured ventricular signals. A determination unit determines an incipient fusion AV-interval from the sensed atrial signals and the detected fusion beats, and a controller controls the pulse generator to deliver stimulation pulses at a controlled AV-interval which is shorter than the incipient fusion AV-interval. The evoked response detector includes an averaging unit which forms an average amplitude value of the measured ventricular signals during a predetermined time window of each cardiac cycle, and a comparator which compares the average value for each cardiac cycle with a predetermined limit criterion, and supplies the result of the comparison to the determination unit for determining a measured ventricular signal resulted from an incipient fusion beat or a completely stimulated capture.

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

AMENDMENT "B" PRIOR TO ACTION

APPLICANTS: Höijer et al. CONFIRMATION NO. 4665

SERIAL NO.: 10/070,470

FILED: March 7, 2002

TITLE: "DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR"

Assistant Commissioner for Patents

Washington, D.C. 20231

Sir:

Applicants herewith amend the above-referenced application as follows, and requests entry of the Amendment prior to examination on the merits.

IN THE SPECIFICATION:

The paragraph beginning at page 1, line 20 of the substitute specification has been amended as follows:

100% pacing in the ventricle requires understanding of a phenomenon referred to as fusion. Fusion means that the natural conduction time, which is the time interval between an atrial activity (a sensed P-wave or a delivered A-pulse) and the subsequent natural ventricular activity (R-wave), is the same as the time (AV-interval) between an atrial activity (again, a sensed P-wave or a delivered A-pulse) and the delivery of a ventricular stimulation pulse (V-pulse). Fusion is thus a condition where the V-pulse is delivered at the same time as the R-wave occurs. Thus, fusion means that the V-pulse occurs when the heart tissue is not capable of responding, i.e. it is refractory, a tissue refractory period starting at the depolarization event (R-wave) and remaining until repolarization (T-wave) occurs. Although not necessarily harmful to the

heart, fusion causes loss of energy in the V-pulse, and should therefore be avoided to save pacemaker battery energy. In the discussion herein, both the time interval between a P-wave or an A-pulse, and a V-pulse will be referred to as the AV-interval.

The paragraph beginning at page 4, line 3 of the substitute specification has been amended as follows:

The above object is achieved in accordance with the principles of the present invention in a heart stimulator having an atrial stimulator and a ventricular stimulator for producing stimulation pulses respectively for delivery to the atrium and the ventricle of a patient's heart, an atrial sensor for sensing atrial signals, an evoked response detector for detecting evoked response signals, a determination unit for determining an incipient fusion AV-interval from the sensed atrial signals and the detected evoked response signals and a control unit for controlling the ventricular stimulator to deliver ventricular stimulation pulses at a controlled AV-interval which is shorter than the incipient fusion AV-interval, wherein the evoked response detector includes an averaging unit which forms an average amplitude value of the evoked response signal during a predetermined time window of each cardiac cycle, and wherein a comparator compares this average value with predetermined limit criteria and supplies a comparison result to the determination unit to allow the determination unit to determine whether a detected evoked response signal results from an incipient fusion beat or a completely stimulated capture.

The paragraph beginning at page 4, line 20 of the substitute specification has been amended as follows:

In the following the expression "sensed atrial signals" denotes sensed spontaneous atrial events P-waves as well as stimulated atrial events (A-pulses). The interval between a sensed spontaneous atrial event and the ventricular V-pulse is denoted by PV interval, and the interval between a stimulated atrial event and the ventricular V-pulse is denoted by AV interval.

The PV interval is generally shorter than the AV interval. As noted above, however, as used herein the PV-interval as well as the AV-interval will be referred to as the AV-interval hereinafter.

IN THE CLAIMS:

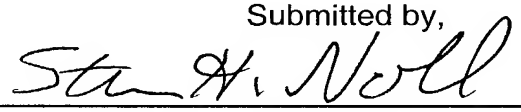
Claim 19 has been amended as follows:

19. (Amended) A heart stimulator as claimed in claim 18 wherein said evoked response detector determines a DC level of said ventricular signals and subtracts said DC level from sampled amplitude value, before said averaging unit forms said average amplitude value.

REMARKS:

The present Amendment corrects typographical errors in the substitute specification, and in claim 19 as presented in Amendment "A" Prior to Action, which were noted after filing. No new matter is added thereby.

Submitted by,



(Reg. 28,982)

SCHIFF, HARDIN & WAITE
CUSTOMER NO. 26574
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606
Telephone: 312/258-5790
Attorneys for Applicants.

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECFICATION

Please amend the paragraph beginning at page 1, line 20 of the substitute specification as follows:

100% pacing in the ventricle requires understanding of a phenomenon referred to as fusion. Fusion means that the natural conduction time, which is the time interval between an atrial activity (a sensed [President-wave] P-wave or a delivered A-pulse) and the subsequent natural ventricular activity (R-wave), is the same as the time (AV-interval) between an atrial activity (again, a sensed P-wave or a delivered A-pulse) and the delivery of a ventricular stimulation pulse (V-pulse). Fusion is thus a condition where the V-pulse is delivered at the same time as the R-wave occurs. Thus, fusion means that the V-pulse occurs when the heart tissue is not capable of responding, i.e. it is refractory, a tissue refractory period starting at the depolarization event (R-wave) and remaining until repolarization (T-wave) occurs. Although not necessarily harmful to the heart, fusion causes loss of energy in the V-pulse, and should therefore be avoided to save pacemaker battery energy. In the discussion herein, both the time interval between a P-wave or an A-pulse, and a V-pulse will be referred to as the AV-interval.

Please amend the paragraph beginning at page 4, line 3 of the substitute specification as follows:

The above object is achieved in accordance with the principles of the present invention in a heart stimulator having an atrial stimulator and a ventricular stimulator for producing stimulation pulses respectively for delivery to the atrium and the ventricle of a patient's heart, an atrial sensor for sensing atrial signals, an evoked response detector for detecting evoked response signals, a determination unit for determining an incipient fusion AV-interval from the sensed atrial signals and the detected evoked response signals and a control unit for controlling the ventricular stimulator to deliver ventricular

stimulation pulses at a controlled AV-interval which is shorter than the incipient fusion AV-interval, wherein the evoked response detector includes an averaging unit which forms an average amplitude value of the evoked response signal during a predetermined time window of each cardiac cycle, and wherein a comparator compares this average value with predetermined limit criteria and supplies a comparison result to the determination unit to allow the determination unit to determine whether a detected evoked response signal results from an incipient fusion [bead=t] beat or a completely stimulated capture.

Please amend the paragraph beginning at page 4, line 20 of the substitute specification as follows:

In the following the expression "sensed atrial signals" denotes sensed spontaneous atrial events [(President-waves)] P-waves as well as stimulated atrial events (A-pulses). The interval between a sensed spontaneous atrial event and the ventricular V-pulse is denoted by PV interval, and the interval between a stimulated atrial event and the ventricular V-pulse is denoted by AV interval. The PV interval is generally shorter than the AV interval. As noted above, however, as used herein the PV-interval as well as the AV-interval will be referred to as the AV-interval hereinafter.

IN THE CLAIMS

Claim 19 has been amended as follows:

19. (Amended) A heart stimulator as claimed in claim 18 wherein said evoked response detector determines [ADC] a DC level of said ventricular signals and subtracts said DC level from sampled amplitude value, before said averaging unit forms said average amplitude value.

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

REQUEST FOR APPROVAL OF DRAWING CHANGES

APPLICANTS:	Höijer et al
ATTORNEY DOCKET NO.	P02,0085
INTERNATIONAL APPLICATION NO:	PCT/SE00/01714
INTERNATIONAL FILING DATE:	September 6, 2000
INVENTION:	"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR" (AS AMENDED)

Assistant Commissioner for Patents,

Washington, D.C.

S I R:

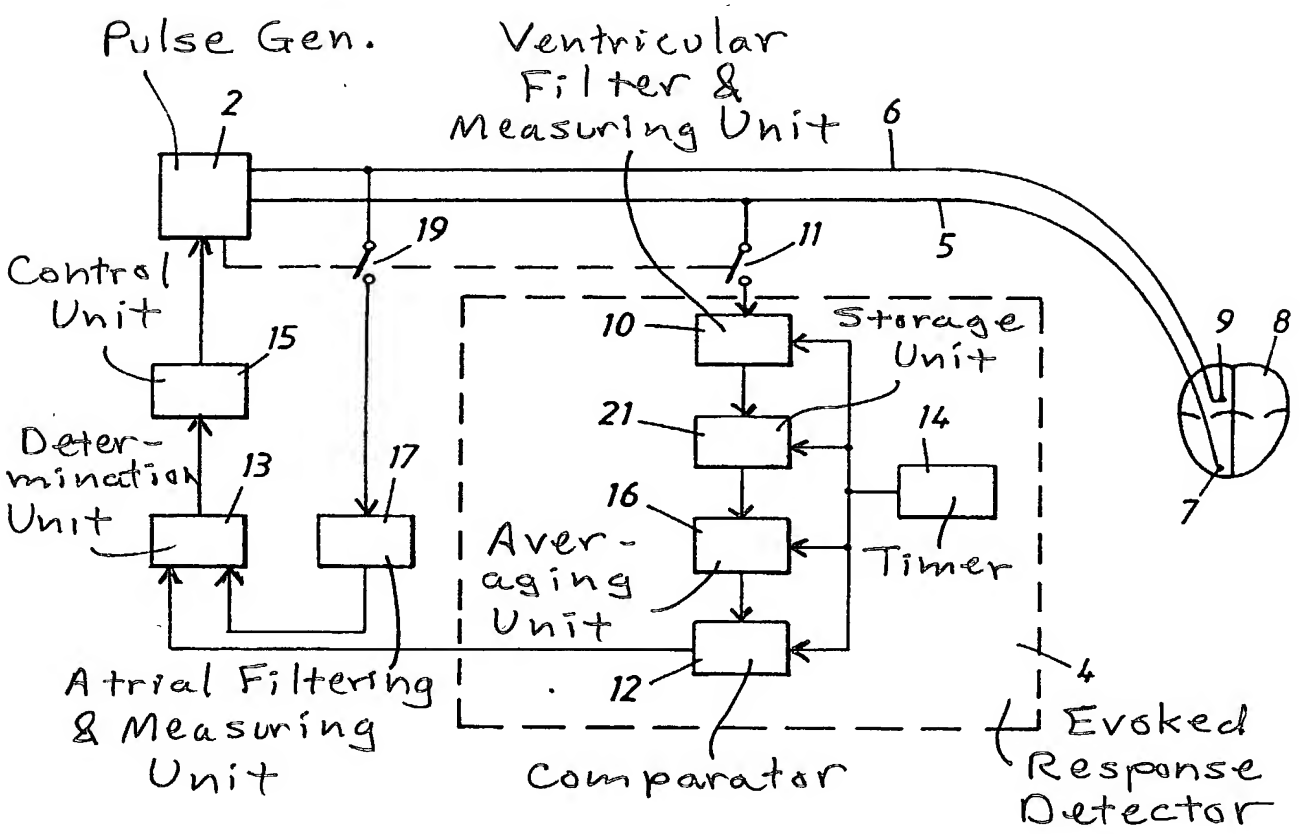
Applicants herewith request approval of the drawing changes in each of Figures 1, 2 and 4, and approval of the further changes on drawing sheets 1-3, as shown on the drawing copies marked in red attached hereto.

Submitted by,

Steven H. Noll (Reg. 28,982)

SCHIFF, HARDIN & WAITE
CUSTOMER NO. 26574
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606
Telephone: 312/258-5790
Attorneys for Applicants.

Fig. 1


Pulse Gen.
2
Ventricular Filter & Measuring Unit
6
19
11
5
Control Unit
15
10
Storage Unit
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21
14
Deter-mination Unit
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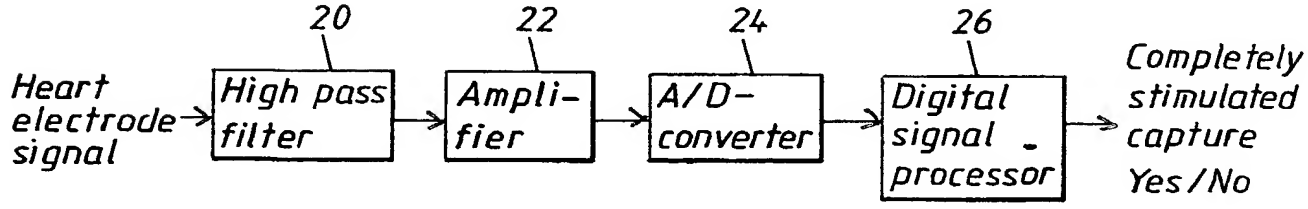
16
Aver-aging Unit
Timer
7
Atrial Filtering & Measuring Unit
12
4
Comparator
Evoked Response Detector

Fig. 2


20
22
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26
Heart electrode signal
High pass filter
Ampli-fier
A/D-converter
Digital signal processor
Completely stimulated capture Yes/No

Fig. 3

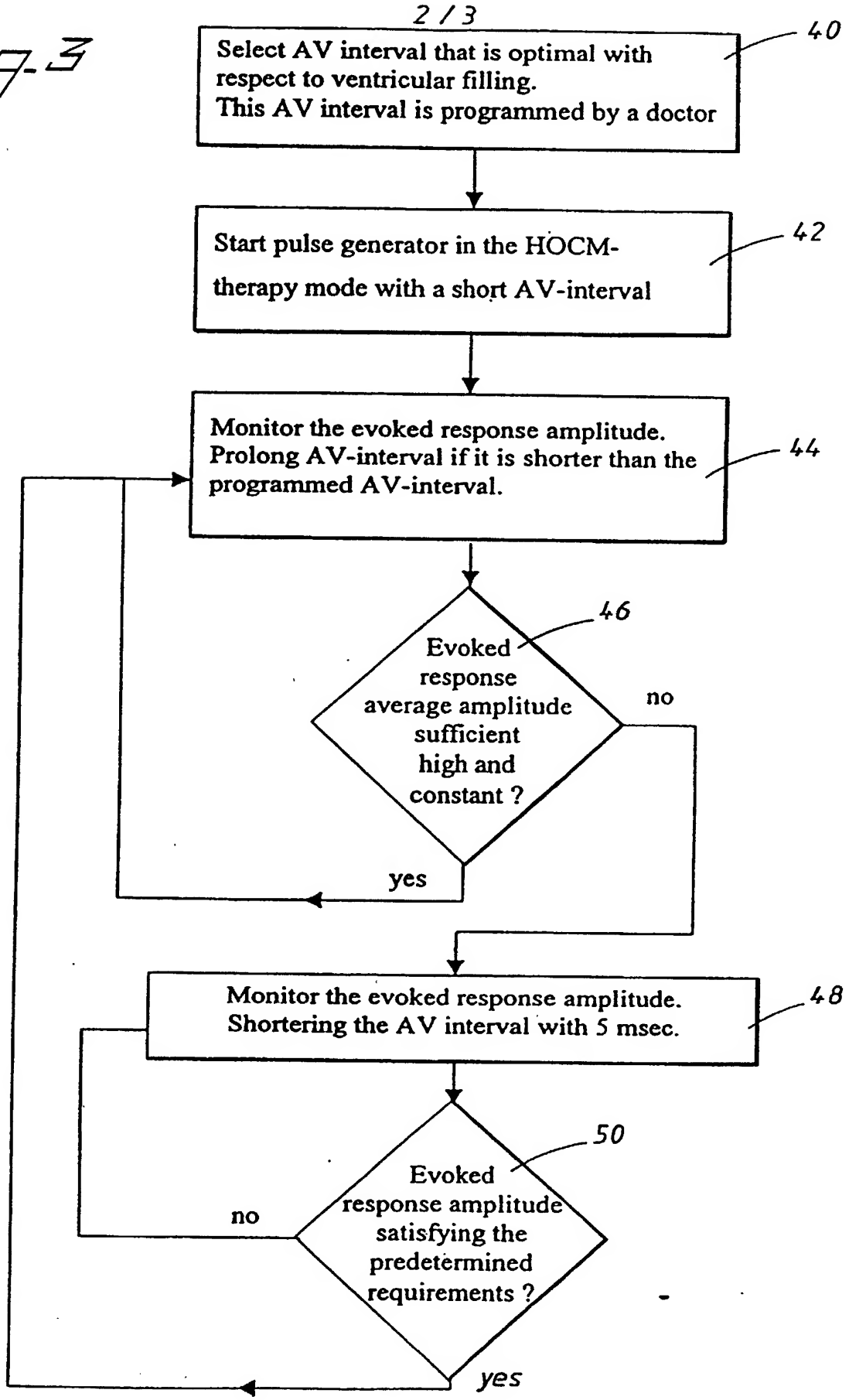
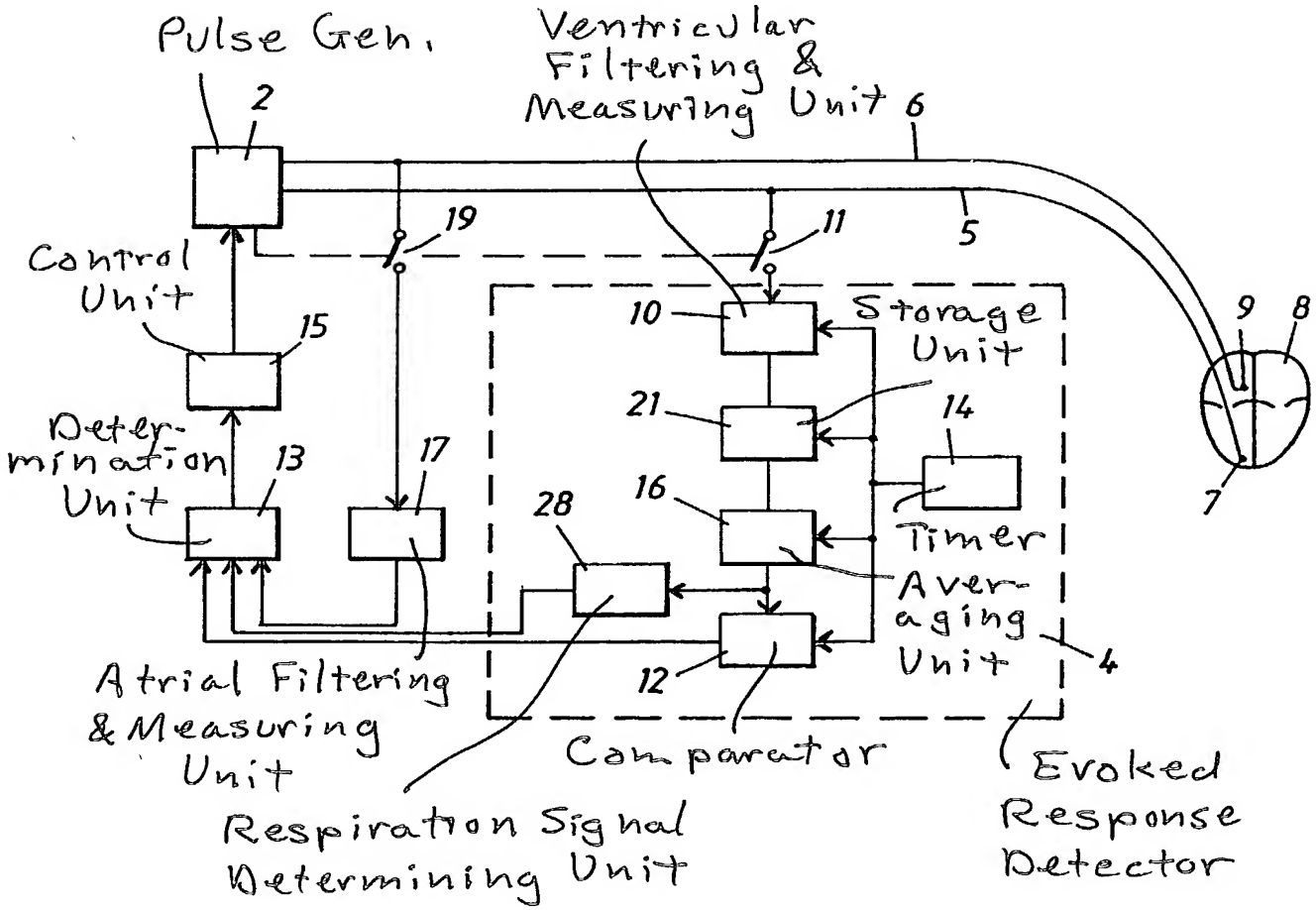

2/3
Select AV interval that is optimal with respect to ventricular filling. This AV interval is programmed by a doctor
40
Start pulse generator in the HOCM-therapy mode with a short AV-interval
42
Monitor the evoked response amplitude. Prolong AV-interval if it is shorter than the programmed AV-interval.
44
Evoked response average amplitude sufficient high and constant ?
46
no
yes
Monitor the evoked response amplitude. Shortering the AV interval with 5 msec.
48
Evoked response amplitude satisfying the predetermined requirements ?
50
no
yes

Fig. 4


Pulse Gen.
2
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11
Control Unit
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Storage Unit
9
8
21
14
Determination Unit
13
17
16
28
Timer
Averaging Unit
4
12
7
Atrial Filtering & Measuring Unit
Comparator
Evoked Response Detector
Respiration Signal Determining Unit

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

SUBMISSION OF DRAWINGS FOR PUBLICATION

APPLICANTS:	Höijer et al
ATTORNEY DOCKET NO.	P02,0085
INTERNATIONAL APPLICATION NO:	PCT/SE00/01714
INTERNATIONAL FILING DATE:	September 6, 2000
INVENTION:	"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR" (AS AMENDED)

Assistant Commissioner for Patents,

Washington, D.C. 20231

S I R:

Applicants herewith submit three sheets (Figs. 1-4) of drawings for the above application which are in suitable form for publication purposes. The drawings embody the changes which were made in the Request for Approval of Drawing Changes filed simultaneously herewith.

Submitted by,

Steven H. Noll (Reg. 28,982)

SCHIFF, HARDIN & WAITE
CUSTOMER NO. 26574
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606
Telephone: 312/258-5790
Attorneys for Applicants.

Fig. 1

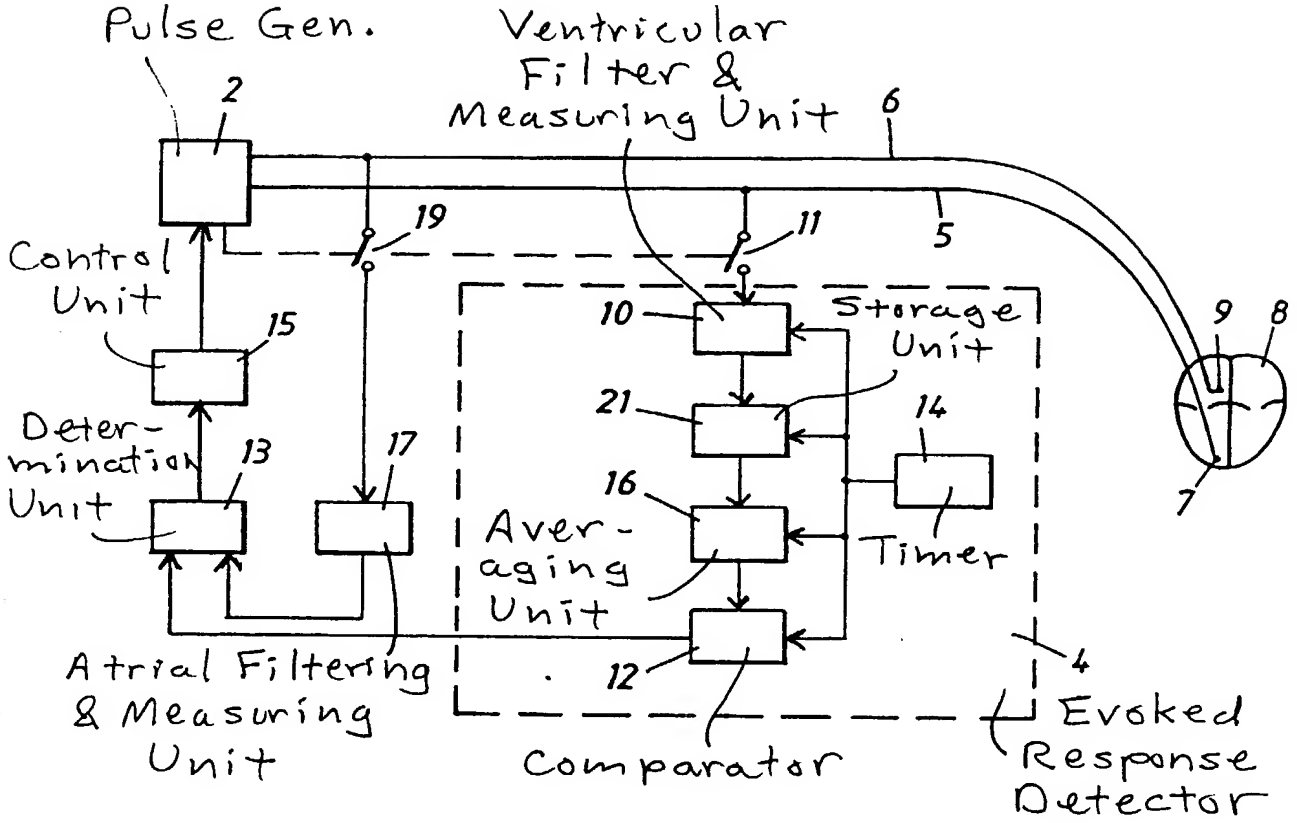
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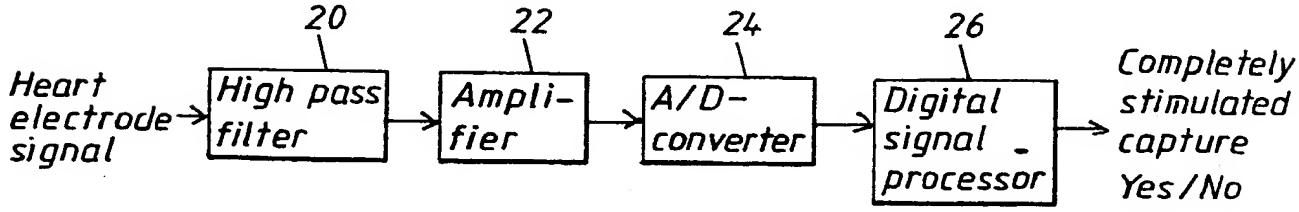
Fig. 2


20
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Heart electrode signal
High pass filter
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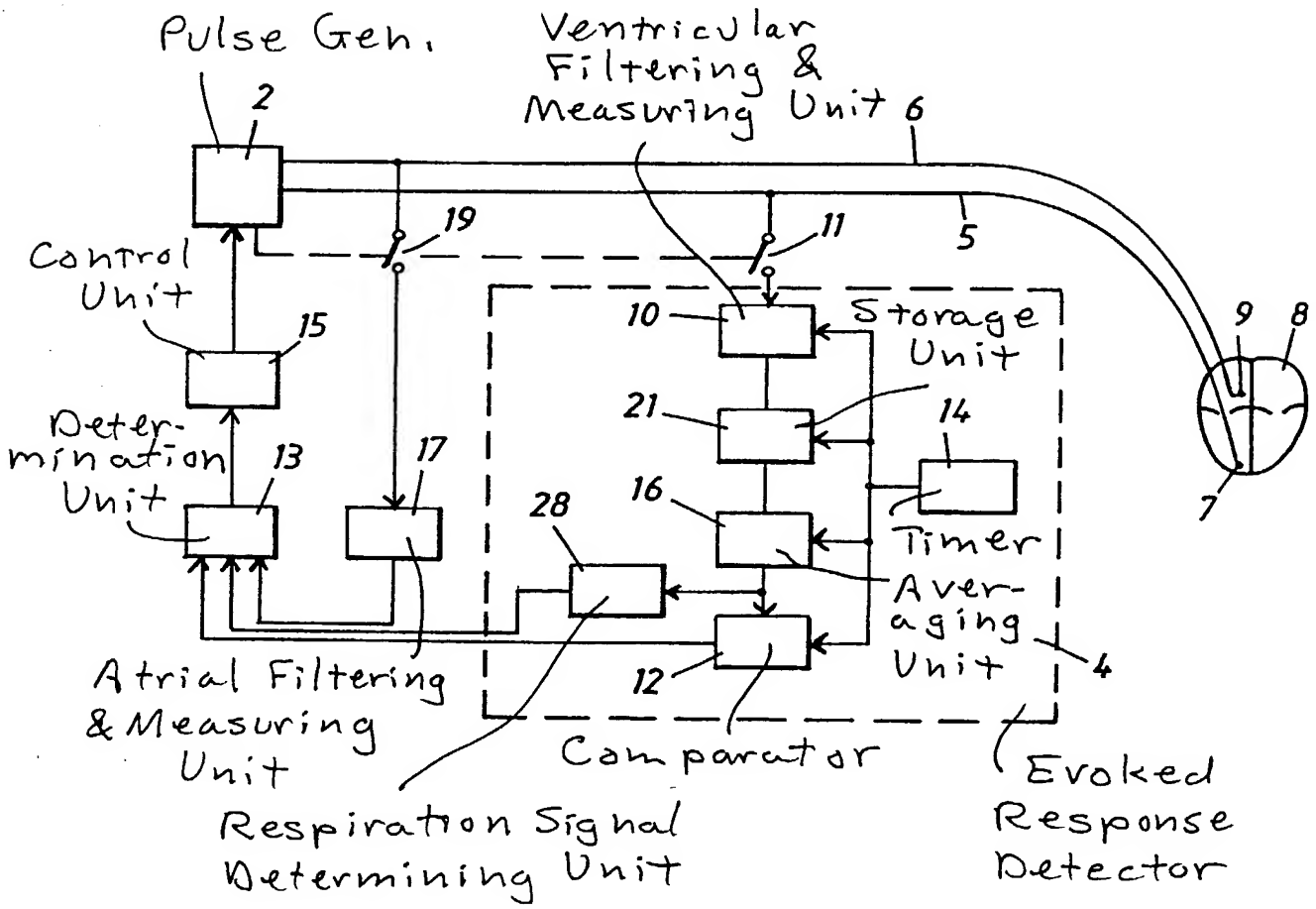
Digital signal processor
Completely stimulated capture Yes/No

Fig. 4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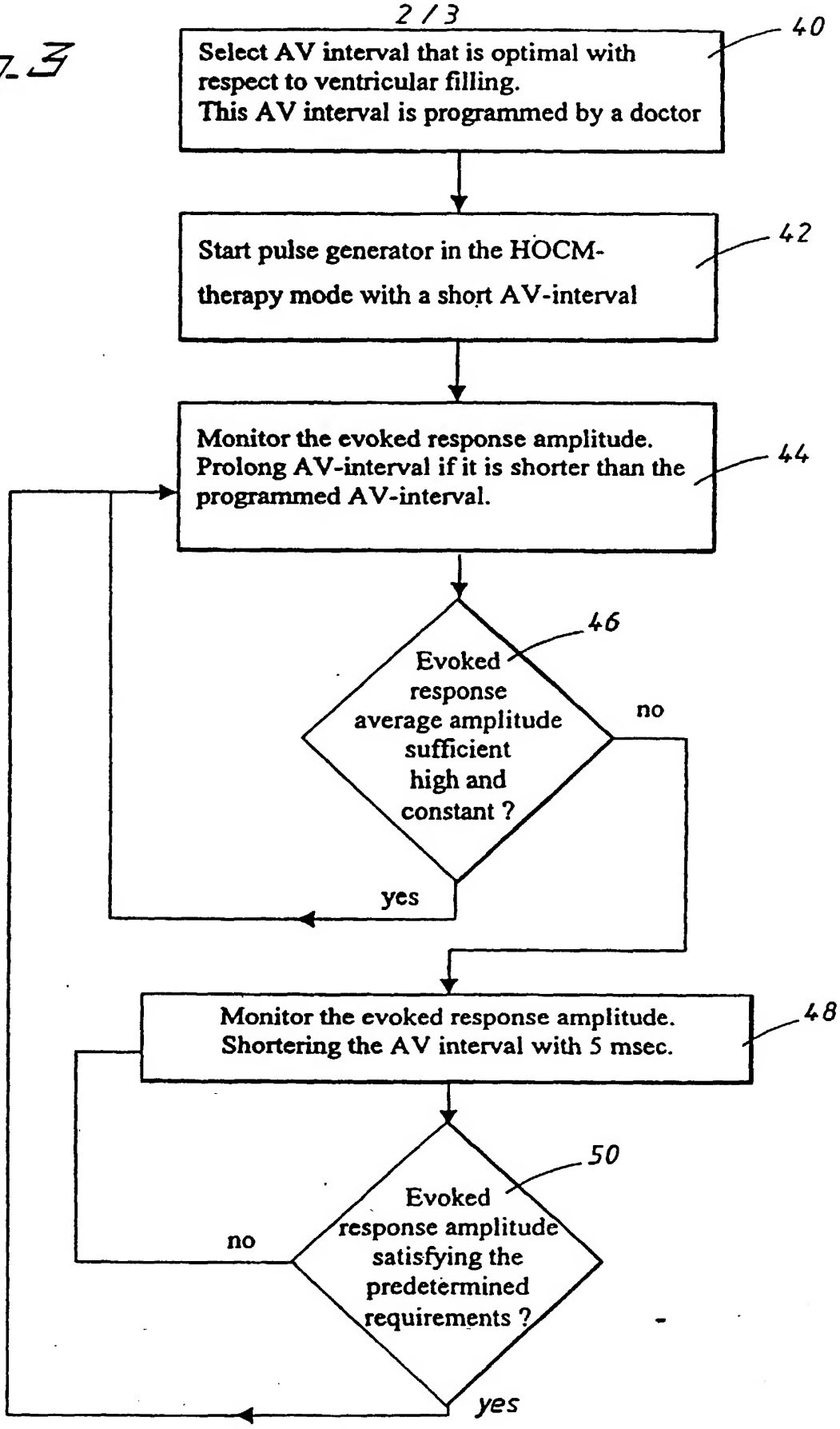
Determination Unit
13
17
16
28
Timer
Averaging Unit
4
12
7
Atrial Filtering & Measuring Unit
Comparator
Evoked Response Detector
Respiration Signal Determining Unit

Fig. 3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SUBSTITUTE SPECIFICATION

SPECIFICATION

TITLE

"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR"

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a heart stimulator, particularly a dual chamber pacemaker with an evoked response detector.

Description of the Prior Art

For certain conditions such as hypertrophic obstructive cardiomyopathy (HOCM) the patient's condition may improve if he or she is paced 100% in the ventricle. In a state of HOCM the left ventricular wall is asymmetrically thickened. The interventricular septum thickness significantly exceeds that of the opposing posterolateral wall. A pressure gradient exists across the left ventricular outflow tract and during ventricular contraction, a progressive degree of outflow tract obstruction results. The conventional site of ventricular pacing is within the right ventricular apex and pacing, prior to intrinsic R-wave excitation, from this site can favorably alter the degree of obstruction. This has been clinically verified.

100% pacing in the ventricle requires understanding of a phenomenon referred to as fusion. Fusion means that the natural conduction time, which is the time interval between an atrial activity (a sensed President-wave or a delivered A-pulse) and the subsequent natural ventricular activity (R-wave),

is the same as the time (AV-interval) between an atrial activity (again, a sensed P-wave or a delivered A-pulse) and the delivery of a ventricular stimulation pulse (V-pulse). Fusion is thus a condition where the V-pulse is delivered at the same time as the R-wave occurs. Thus, fusion means that the V-pulse occurs when the heart tissue is not capable of responding, i.e. it is refractory, a tissue refractory period starting at the depolarization event (R-wave) and remaining until repolarization (T-wave) occurs. Although not necessarily harmful to the heart, fusion causes loss of energy in the V-pulse, and should therefore be avoided to save pacemaker battery energy. In the discussion herein, both the time interval between a P-wave or an A-pulse, and a V-pulse will be referred to as the AV-interval.

To obtain 100% pacing beats with no fusion, very short AV delays have been used. Such very short AV intervals are, however, non-physiologic and therefore it is highly desirable to prolong the AV interval while maintaining a continuous monitoring of fusion, such that the AV interval would be shortened automatically if fusion beats appear. Several attempts have been made to solve this problem.

Thus, United States Patent Nos. 5,534,016 and 5,713,930 describe techniques for optimizing the AV interval for therapeutic purposes for patients having HOCM. In the system according to United States Patent No. 5,534,016 the T-wave detection is monitored to detect when the AV interval is lengthened to the point of evoking a fusion beat, and in the system disclosed in United States Patent No. 5,713,930 the relationship between AV

intervals and OT intervals (= the time interval between a delivered ventricular stimulus and resulting T-wave) is monitored and therefrom it is determined when AV intervals correspond to full capture and when AV intervals correspond to fusion.

Further, in United States Patent No. 5,507,782 a dual chamber pacemaker is described in which the longest AV interval which results in complete ventricular capture is determined from the wave form of the ventricular depolarization R-wave following a ventricular pacing pulse for the purpose of treating patients suffering from HOCM. In this document the problems related to fusion beats and the transition region between complete pacing and fusion are not at all dealt with.

Another way of solving the problem of fusion and providing a 100% pacing of the ventricle is by AV node ablation. AV node ablation is, however, an intervention associated with extra costs and the conduction pathway from the atria to the ventricles is then permanently destroyed so the patient will be completely dependent on a pacemaker in the future with higher clinical risks in the event of a pacemaker failure.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a heart stimulator suitable for treating HOCM patients by accomplishing 100% paced ventricular capture, which stimulator comprises a new type of evoked

response detector suitable for detecting incipient fusion in a simple and reliable way.

The above object is achieved in accordance with the principles of the present invention in a heart stimulator having an atrial stimulator and a ventricular stimulator for producing stimulation pulses respectively for delivery to the atrium and the ventricle of a patient's heart, an atrial sensor for sensing atrial signals, an evoked response detector for detecting evoked response signals, a determination unit for determining an incipient fusion AV-interval from the sensed atrial signals and the detected evoked response signals and a control unit for controlling the ventricular stimulator to deliver ventricular stimulation pulses at a controlled AV-interval which is shorter than the incipient fusion AV-interval, wherein the evoked response detector includes an averaging unit which forms an average amplitude value of the evoked response signal during a predetermined time window of each cardiac cycle, and wherein a comparator compares this average value with predetermined limit criteria and supplies a comparison result to the determination unit to allow the determination unit to determine whether a detected evoked response signal results from an incipient fusion bead=t or a completely stimulated capture.

In the following the expression "sensed atrial signals" denotes sensed spontaneous atrial events (President-waves) as well as stimulated atrial events (A-pulses). The interval between a sensed spontaneous atrial event and the ventricular V-pulse is denoted by PV interval, and the interval

between a stimulated atrial event and the ventricular V-pulse is denoted by AV interval. The PV interval is generally shorter than the AV interval. As noted above, however, as used herein the PV-interval as well as the AV-interval will be referred to as the AV-interval hereinafter.

Thus, in the stimulator according to the present invention the AV-interval is continuously monitored and automatically shortened if incipient fusion is detected. Incipient fusion is detected by an evoked response detector from measured ventricular signals picked up by an ventricular electrode and containing the evoked response signal, and the AV-interval will be adjusted accordingly to be as long as possible while avoiding the occurrence of fusion beats. From a hemodynamic point of view, e.g. ventricular filling and cardiac output, such a stimulator operation will give optimum results. Thus the stimulator according to the invention will operate with an AV-interval that is optimized with respect to hemodynamic conditions.

In an embodiment of the heart stimulator according to the invention, the control unit is adapted to modulate the AV-interval with a predetermined amount, and the comparator is adapted to compare the variation of the average amplitude values obtained during the time window with a predetermined limit. A large variability is then a clear indication of incipient fusion.

In another embodiment, the control unit is adapted to regularly prolong the AV- interval with a predetermined amount and the comparator is adapted to compare the average amplitude values obtained during the

time window of cardiac cycles with the predetermined limit value and/or compare the variation of the average amplitude values obtained during the time window with a predetermined limit. In this way, incipient fusion can be detected at a very early stage and by utilizing both an amplitude criterion and a variability criterion improved reliability is obtained.

In a further embodiment of the heart stimulator according to the invention the evoked response detector is adapted to determine the DC level of the measured ventricular signal and subtract this DC level from each sample before the average value is formed. It is important to subtract the DC level from, the measured signal picked up by the electrode to get a corrected signal for subsequent analysis.

In another embodiment of the heart stimulator according to the invention a respiration signal determining unit is provided for determining a respiration signal representing the respiration rate of the patient, from a predetermined number of the average values.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of the basic components of a heart stimulator constructed and operating in accordance with the principles of the present invention.

Figure 2 is a block diagram of the evoked response detector of the heart stimulator according to the invention.

Figure 3 is a flowchart illustrating the operation of the inventive embodiment shown in Figures 1 and 2.

Figure 4 is a block diagram of the basic components of a second embodiment of a heart stimulator constructed and operating in accordance with the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is known to distinguish between completely stimulated captures, fusion beats and losses of capture from analysis of average amplitude values of recorded ventricular signals during a predetermined time window after a pacemaker stimulation, see Åsa Uhrenius et al., "Evaluation of new Algorithms for Autocapture with Unipolar Leads", CARDIOSTIM 98, Nice, June 1998.

Figure 1 shows a block diagram of the basic components of the heart stimulator according to the invention. The stimulator has a pulse generator 2 which through leads 5, 6 and associated atrial and ventricular electrodes 7, 9 are connected to the heart 8 of a patient. The pulse generator 2 is devised to produce stimulation pulses of varying amplitudes which through the leads 5, 6 with their electrodes 7, 9 are transferred to the heart 8. An evoked response detector 4 of the above mentioned type is connected to the ventricular lead 5. An atrial detector having an atrial filtering and measuring unit 17 is connected to the lead 6 for measuring amplitudes of signals picked up by the atrial electrode 9. A determination unit 13 is connected to the

evoked response detector 4 and to the atrial filtering and measuring unit 17 for determining an incipient fusion AV-interval, i.e. the AV-interval at which incipient fusion was detected, from the measured atrial signals and detected incipient fusion beats. A control unit 15 is connected to the determination unit 13 and to the pulse generator 2 for controlling the pulse generator 2 to deliver stimulation pulses at a controlled AV interval which is shorter than the incipient fusion AV-interval.

The atrial filter and measurement unit 17 and the evoked response detector 4 are disconnected by switches 19 and 11 from their respective leads 5, 6 during stimulation.

The evoked response detector 4 has filter and measuring unit 10. The filtered ventricular signals picked up by the ventricular electrode 7 are supplied to a storage unit 21, an averaging unit 16 and to a comparator 12 for detecting incipient fusion by comparing the average amplitude obtained during a predetermined time window of the cardiac cycle from the averaging unit 16 with suitably selected limit values. As follows from the above mentioned publication by Åsa Uhrenius et al. completely stimulated captures result in a comparatively large constant average amplitude whereas an incipient fusion results in a decrease of the absolute value of this average amplitude.

As an alternative, the averaging unit 16 can be adapted to form a running average value of the measured ventricular signals during the predetermined time window from a predetermined number of the latest

cardiac cycles and the comparator 12 can be adapted to receive the running average value and compare the average value obtained during the time window of each cardiac cycle with the running average value from immediately preceding cardiac cycles.

The above mentioned limit values of the comparator 12 can be selected such that e.g. a 10% decrease of the measured average amplitude compared to the average amplitude in a situation of completely stimulated capture is indicated as an incipient fusion. Thus, a decrease of the absolute value of the average amplitude from e.g. 26mV to e.g. 23, 5mV can be interpreted as incipient fusion. In this case, a running-average value as described above of e.g. the ten last cardiac cycles, is suitably used as limit value in the comparator 12 for obtaining an acceptable signal-to-noise ratio.

A timer 14 is provided for determining the evoked response time window during which the ventricular signal is measured and stored. This evoked response window normally extends from 15 to 55 msec after stimulation.

Thus, after a blanking time of about 15 msec the measured evoked ventricular signal is sampled and digitized during this evoked response time window and the average value of these samples is formed. This procedure is performed in the averaging unit 16, which thus supplies to the comparator 12 an average amplitude value obtained during the time window for each heart beat. A suitable sampling frequency can be e.g. 512 Hz, which results in about 20 samples per beat.

As also follows from the publication by Åsa Uhrenius et al., the variation in the average amplitude from different cardiac cycles is comparatively small in a situation of completely stimulated capture, whereas this variation increases in a fusion situation. Thus, as an alternative embodiment, the comparator 12 can be adapted to compare the variability of average amplitude values obtained from different cardiac cycles with a predetermined variability limit to detect an incipient fusion.

The variability criterion for indicating incipient fusion normally should be more strict than the above discussed amplitude criterion. Thus, a variability increase in the average amplitude values of e.g. 25% compared to the variability at completely stimulated capture can be used as variability criterion in the comparator 12 for indicating incipient fusion. An increase of the peak to peak variability in the average amplitude values from different cardiac cycles from e.g. 2.5 mV to e.g. 3.0 mV can be interpreted as incipient fusion. Also is this case a running average value from e.g. the ten latest cardiac cycles should preferably be used.

As a further version of this embodiment, the control unit 15 can be adapted to carefully modulate the AV-interval with e.g. ±5 msec or ±10 msec. A large variability appearing in the average amplitudes is then a reliable indication of fusion.

As still another alternative, the control unit 15 can be adapted to prolong at regular intervals the AV-interval with a predetermined amount, e.g. 10 msec, and the average amplitude or variability criteria described above

are checked. If the average amplitude or variability criteria then, for this prolonged AV-interval, indicate fusion or incipient fusion, the AV-interval is shortened by 20 msec. If no changes in average amplitude or variability are noted, the AV-interval is the correct one. This would mean that the heart stimulator chooses an AV-interval which is approximately 20 msec shorter than the AV-interval at which incipient fusion is detected. In this way, a type of check is performed to determine if the heart stimulator operates close to fusion, and in this way incipient fusion can be detected at a very early stage.

In the heart stimulator according to the invention it is also possible to utilize both above described amplitude and variability criteria for determining an incipient fusion which normally further improves the detection reliability.

To obtain a reliable result it is also desirable to eliminate any DC level in the measured ventricular signal. This can be performed by sampling the measured ventricular signal before the emission of a stimulation pulse and forming an average value of these samples during a cardiac cycle. This average value represents the DC level and is subtracted from each sample of the subsequent measured ventricular signal.

Figure 2 shows in greater detail one embodiment of the evoked response detector of the heart stimulator according to the invention. The ventricular signal picked up by the lead 5 with its electrode 7 in Figure 1 is supplied to a highpass filter 20. An amplifier 22 and an A/D converter 24 are provided for amplifying and A/D converting respectively the filtered signal. A digital signal processor 26 calculates the average amplitudes of the

measured ventricular signals and compares them with suitably selected limit values as described above for detecting an incipient fusion.

Figure 3 is a flow chart illustrating the function of the embodiment illustrated in Figures 1 and 2 of the heart stimulator according to the invention for achieving 100% paced ventricular capture while optimizing the AV-interval with respect to hemodynamic conditions. In step 40 an AV interval is selected which is optimal with respect to the ventricular filling of the patient in question. This AV interval is programmed by a doctor. The pulse generator 2 starts the HOCM therapy mode with a short AV-interval, step 42.

The evoked response signal average amplitude during each heart beat is monitored by the evoked response detector 4, and the AV interval is prolonged if it is shorter than the programmed AV interval, step 44.

It is checked that the evoked response average amplitude has a sufficiently high, substantially constant absolute value, in step 46. If so, the AV-interval is prolonged while monitoring the evoked response amplitude according to step 44. If not, the AV-interval is shortened with e.g. 5 msec while monitoring the evoked response amplitude, at step 48.

It is then checked whether the average value formed from sampled values of the evoked response signal as described above maintains a sufficiently high and constant absolute value according to the predetermined requirements, in step 50. If so, the procedure reverts to step 44, viz. the AV-interval is once again prolonged, provided that it is shorter than the

programmed AV-interval, while monitoring the evoked response amplitude, and the procedure is continued to step 46 as described above. If not, the procedure reverts to step 48, viz, the AV-interval is further shortened with 5 msec while monitoring the evoked response amplitude.

Thus the heart stimulator according to the invention is operating at an AV-interval which is as close as possible to the optimal AV-interval programmed by a doctor while securing all the time that occurrence of fusion is avoided. In this way a continuous suboptimization is obtained of the programmed optimal AV-interval set by the doctor. If the evoked response average amplitude does not satisfy predetermined criteria with respect to the absolute averaged value of the amplitude and possibly the variability of the amplitude, the AV-interval is automatically shortened until these criteria are again satisfied.

Figure 4 is a block diagram of the basic components of a second embodiment of the heart stimulator according to the invention.

This embodiment has, in addition to the elements of the embodiment shown in Figure 1, a respiration signal determining unit 28, which is supplied with the average signal values generated by the averaging unit 16. The respiration signal determining unit 28 generates a respiration signal, representing the respiration rate of the patient, from a predetermined number of evoked response average values. The respiration signal is supplied to the AV-interval determining unit for use in the control of the pulse generator 2. The use of the respiration rate to control the operation of a pacemaker, is

well known to the person skilled in the art, cf. e.g. United States Patent No. 4,702,253, and is therefore not described herein.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

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SPECIFICATION

TITLE

"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR"

BACKGROUND OF THE INVENTION

[HEART STIMULATOR

Technical Field]

Field of the Invention

The present invention relates to a heart stimulator, particularly a dual chamber pacemaker with an evoked response detector [according to the preamble of claim 1].

[Background Art]

Description of the Prior Art

For certain conditions such as hypertrophic obstructive cardiomyopathy (HOCM) the patient's condition may improve if he or she is paced [to] 100% in the ventricle. In a state of HOCM the left ventricular wall is asymmetrically thickened. The interventricular septum thickness significantly exceeds that of the opposing posterolateral wall. A pressure gradient exists across the left ventricular outflow tract and during ventricular contraction, a progressive degree of outflow tract obstruction results. The conventional site of ventricular pacing is within the right ventricular apex and pacing, prior to intrinsic R-wave excitation, from this site can [favourably] favorably alter the degree of obstruction. This has been clinically verified.

100% pacing in the ventricle requires understanding of a phenomenon referred to as fusion. Fusion means that the natural conduction time, which is the time interval between an atrial activity (a sensed President-wave or a

delivered A-pulse) and the subsequent natural ventricular activity (R-wave), is the same as the time (AV-interval) between an atrial activity (again, a sensed P-wave or a delivered A-pulse) and the delivery of a ventricular stimulation pulse (V-pulse). Fusion is thus a condition where the V-pulse is delivered at the same time as the R-wave occurs. Thus, fusion means that the V-pulse occurs when the heart tissue is not capable of responding, i.e. it is refractory, a tissue refractory period starting at the depolarization event (R-wave) and remaining until repolarization (T-wave) occurs. Although not necessarily harmful to the heart, fusion causes loss of energy in the V-pulse, and should therefore be avoided to save pacemaker battery energy. [For] In the [purposes of this application] discussion herein, both the time interval between a P-wave or an A-pulse, and a V-pulse will be referred to as the AV-interval.

To obtain 100% pacing beats with no fusion, very short AV delays have been used. Such very short AV intervals are, however, non-physiologic and therefore it is highly desirable to prolong the AV interval while maintaining a continuous monitoring of fusion, such that the AV interval would be shortened automatically if fusion beats appear. Several attempts have been made to solve this problem.

Thus, [US-A-] United States Patent Nos. 5,534,016 and 5,713,930 describe techniques for optimizing the AV interval for therapeutic purposes for patients having HOCM. In the system according to [US-A-] United States Patent No. 5,534,016 the T-wave detection is monitored to detect when the

AV interval is lengthened to the point of evoking a fusion beat, and in the system disclosed in [US-A-] United States Patent No. 5,713,930 the relationship between AV intervals and OT intervals (= the time interval between a delivered ventricular stimulus and resulting T-wave) is monitored and therefrom it is determined when AV intervals correspond to full capture and when AV intervals correspond to fusion.

Further, in [US-A-] United States Patent No. 5,507,782 a dual chamber pacemaker is described in which the longest AV interval [providing for] which results in complete ventricular capture is determined from the wave form of the ventricular depolarization R-wave following a ventricular pacing pulse for the purpose of treating patients suffering from HOCM. In this document the problems related to fusion beats and the transition region between complete pacing and fusion are not at all dealt with.

Another way of solving the problem of fusion and providing a 100% pacing of the ventricle is by AV node ablation. AV node ablation is, however, an intervention associated with extra costs and the conduction pathway from the atria to the ventricles is then permanently destroyed [for all time] so the patient will be completely [depending] dependent on a pacemaker in the future with higher clinical risks in the event of a pacemaker failure.

SUMMARY OF THE INVENTION

[The purpose] An object of the present invention is to provide a [new] heart stimulator suitable for treating HOCM patients by accomplishing 100% paced ventricular capture, which stimulator comprises a new type of evoked

response detector suitable for detecting incipient fusion in a simple and reliable way.

[Summary of the invention

This purpose is obtained by a heart stimulator of the type defined in the introductory portion of this description having the characterizing features of claim 1.]

The above object is achieved in accordance with the principles of the present invention in a heart stimulator having an atrial stimulator and a ventricular stimulator for producing stimulation pulses respectively for delivery to the atrium and the ventricle of a patient's heart, an atrial sensor for sensing atrial signals, an evoked response detector for detecting evoked response signals, a determination unit for determining an incipient fusion AV-interval from the sensed atrial signals and the detected evoked response signals and a control unit for controlling the ventricular stimulator to deliver ventricular stimulation pulses at a controlled AV-interval which is shorter than the incipient fusion AV-interval, wherein the evoked response detector includes an averaging unit which forms an average amplitude value of the evoked response signal during a predetermined time window of each cardiac cycle, and wherein a comparator compares this average value with predetermined limit criteria and supplies a comparison result to the determination unit to allow the determination unit to determine whether a detected evoked response signal results from an incipient fusion bead=t or a completely stimulated capture.

In the following the expression "sensed atrial signals" denotes sensed spontaneous atrial events (President-waves) as well as stimulated atrial events (A-pulses). The interval between a sensed spontaneous atrial event and the ventricular V-pulse is denoted by PV interval, and the interval between a stimulated atrial event and the ventricular V-pulse is denoted by AV interval. The PV interval is generally shorter than the AV interval. As noted above, however, [for the purpose of this patent application] as used herein the PV-interval as well as the AV-interval will be referred to as the AV-interval hereinafter.

Thus, in the stimulator according to the present invention the AV-interval is continuously monitored and automatically shortened if incipient fusion is detected. [Thus an incipient] Incipient fusion is detected by an evoked response detector from measured ventricular signals picked up by an ventricular electrode and containing the evoked response signal, and the [used] AV-interval will be adjusted accordingly to be as long as possible while avoiding the occurrence of fusion beats. From a [haemodynamic] hemodynamic point of view, e.g. ventricular filling and cardiac output, such a stimulator operation will give optimum results. Thus the stimulator according to the invention will operate with an AV-interval that is optimized with respect to [haemodynamic] hemodynamic conditions.

[According to] In an [advantageous] embodiment of the heart stimulator according to the invention, the [controlling means are] control unit is adapted to modulate the AV-interval with a predetermined amount, and

[said comparison means] the comparator is adapted to [then] compare the variation of [said] the average amplitude values obtained during [said] the time window with a predetermined limit. A large variability is then a clear indication of incipient fusion.

[According to] In another [advantageous] embodiment, [said controlling means are] the control unit is adapted to regularly prolong the AV-interval with a predetermined amount and [said comparison means] the comparator is adapted to [then] compare [said] the average amplitude values obtained during [said] the time window of cardiac cycles with [said] the predetermined limit value and/or compare the variation of [said] the average amplitude values obtained during [said] the time window with a predetermined limit. In this way, incipient fusion can be detected at a very early stage and by utilizing both an amplitude criterion and a variability criterion improved reliability is obtained.

[According to still another advantageous] In a further embodiment of the heart stimulator according to the invention the evoked response detector is adapted to determine the DC level of the measured ventricular signal and subtract this DC level from each sample before the average value is formed. It is important to subtract the DC level from, the measured signal picked up by the electrode to get a corrected signal for subsequent analysis.

[According to yet] In another [advantageous] embodiment of the heart stimulator according to the invention a respiration signal determining [means] unit is provided for determining a respiration signal representing the

respiration rate of the patient, from a predetermined number of [said] the average values.

[Brief Description of the Drawings

To explain the invention more in detail, selected embodiments of the heart stimulator according to the invention will now be described with reference to the drawings, on which figure 1 is a block diagram of the principal layout of the heart stimulator according to the invention, figure 2 is a block diagram of the evoked response detector of the heart stimulator according to the invention, figure 3 is a flow diagram illustrating the function of the embodiment of figures 1 and 2, and figure 4 is a block diagram of the principal layout of a second embodiment of the heart stimulator according to the invention.

Description of Preferred Embodiments]

DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of the basic components of a heart stimulator constructed and operating in accordance with the principles of the present invention.

Figure 2 is a block diagram of the evoked response detector of the heart stimulator according to the invention.

Figure 3 is a flowchart illustrating the operation of the inventive embodiment shown in Figures 1 and 2.

Figure 4 is a block diagram of the basic components of a second embodiment of a heart stimulator constructed and operating in accordance with the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is [previously] known to distinguish between completely stimulated captures, fusion beats and losses of capture from analysis of average amplitude values of recorded ventricular signals during a predetermined time window after a pacemaker stimulation, see Åsa Uhrenius et al., "Evaluation of new Algorithms for Autocapture with Unipolar Leads", CARDIOSTIM 98, Nice, June 1998.

Figure 1 shows a block diagram of the [principal layout] basic components of the heart stimulator according to the invention. The stimulator [comprises] has a pulse generator 2 which through leads 5, 6 and associated atrial and ventricular electrodes 7, 9 are connected to the heart 8 of a patient. The pulse generator 2 is devised to produce stimulation pulses of varying amplitudes which through the leads 5, 6 with their electrodes 7, 9 are transferred to the heart 8. An evoked response detector 4 of the above mentioned type is connected to the ventricular lead 5. An atrial detector [comprising] having an atrial filtering and measuring [means] unit 17 is connected to the lead 6 for measuring amplitudes of signals picked up by the atrial electrode 9. [Determining means] A determination unit 13 [are] is connected to the evoked response detector 4 and to [said] the atrial filtering and measuring [means] unit 17 for determining an incipient fusion

AV-interval, i.e. the AV-interval at which incipient fusion was detected, from [said] the measured atrial signals and detected incipient fusion beats. [Controlling means] A control unit 15 [are] is connected to the [determining means] determination unit 13 and to the pulse generator 2 for controlling the pulse generator 2 to deliver stimulation pulses at a controlled AV interval which is shorter than [said] the incipient fusion AV-interval.

The atrial filter and measurement [means] unit 17 and the evoked response detector 4 are disconnected by switches 19 and 11 from their respective leads 5, 6 during stimulation.

The evoked response detector 4 [comprises] has filter and measuring [means] unit 10. The filtered ventricular signals picked up by the ventricular electrode 7 are supplied to a storage [means] unit 21, an averaging [means] unit 16 and to [comparison means] a comparator 12 for detecting incipient fusion by comparing the average amplitude obtained during a predetermined time window of the cardiac cycle from the averaging [means] unit 16 with suitably selected limit values. As [appears] follows from the above mentioned publication by Åsa Uhrenius et al. completely stimulated captures result in a comparatively large constant average amplitude whereas an incipient fusion results in a decrease of the absolute value of this average amplitude.

As an alternative, the averaging [means] unit 16 can be adapted to form a running average value of the measured ventricular signals during [said] the predetermined time window from a predetermined number of the

latest cardiac cycles and the [comparison means] comparator 12 can be adapted to receive [said] the running average value and compare the average value obtained during [said] the time window of each cardiac cycle with [said] the running average value from immediately preceding cardiac cycles.

The above mentioned limit values of the [comparison means] comparator 12 can be selected such that e.g. a 10% decrease of the measured average amplitude compared to the average amplitude in a situation of completely stimulated capture is indicated as an incipient fusion. Thus, a decrease of the absolute value of the average amplitude from e.g. 26mV to e.g. 23, 5mV can be interpreted as incipient fusion. In this case, a running-average value as described above of e.g. the ten last cardiac cycles, is suitably used as limit value in the [comparison means] comparator 12 for obtaining an acceptable signal-to-noise ratio.

[Timing means] A timer 14 [are] is provided for determining [said] the evoked response time window during which the ventricular signal is measured and stored. This evoked response window normally extends from 15 to 55 msec after stimulation.

Thus, after a blanking time of about 15 msec the measured evoked ventricular signal is sampled and digitized during this evoked response time window and the average value of these samples is formed. This procedure is performed in the averaging [means] unit 16, which thus supplies to the [comparison means] comparator 12 an average amplitude value obtained

during [said] the time window for each heart beat. A suitable sampling frequency can be e.g. 512 Hz, which results in about 20 samples per beat.

As also [appears] follows from the publication by Åsa Uhrenius et al., the variation in the average amplitude from different cardiac cycles is comparatively small in a situation of completely stimulated capture, whereas this variation increases in a fusion situation. Thus, as an alternative embodiment, the [comparison means] comparator 12 can be adapted to compare the variability of average amplitude values obtained from different cardiac cycles with a predetermined variability limit to detect an incipient fusion.

The variability criterion for indicating incipient fusion [should] normally should be more strict than the above discussed amplitude criterion. Thus, a variability increase in the average amplitude values of e.g. 25% compared to the variability at completely stimulated capture can be used as variability criterion in the [comparison means] comparator 12 for indicating incipient fusion. An increase of the peak to peak variability in the average amplitude values from different cardiac cycles from e.g. [2,5mV] 2.5 mV to e.g. [3, 0mV] 3.0 mV can be interpreted as incipient fusion. Also is this case a running average value from e.g. the ten latest cardiac cycles should preferably be used.

As a further [improvement] version of this embodiment, the [controlling means] control unit 15 can be adapted to carefully modulate the AV-interval

with e.g. ±5 msec or ±10 msec. A large variability appearing in the average amplitudes is then a reliable indication of fusion.

As still another alternative, the [controlling means] control unit 15 can be adapted to prolong at regular intervals the AV-interval with a predetermined amount, e.g. 10 msec, and the average amplitude or variability criteria described above are checked. If the average amplitude or variability criteria then, for this prolonged AV-interval, indicate fusion or incipient fusion, the AV-interval is shortened by 20 msec. If no changes in average amplitude or variability are noted, the AV-interval is the correct one. This would mean that the heart stimulator chooses an AV-interval which is approximately 20 msec shorter than the AV-interval at which incipient fusion is detected. In this way, a [kind] type of check is performed to determine if the heart stimulator operates close to fusion, and in this way incipient fusion can be detected at a very early stage.

In the heart stimulator according to the invention it is also possible to utilize both above described amplitude and variability criteria for determining an incipient fusion which normally further improves the detection reliability.

To obtain a reliable result it is also desirable to eliminate any DC level in the measured ventricular signal. This can be performed by sampling the measured ventricular signal before the emission of a stimulation pulse and forming an average value of these samples during a cardiac cycle. This average value represents the DC level and is subtracted from each sample of the subsequent measured ventricular signal.

Figure 2 shows in greater detail one embodiment of the evoked response detector of the heart stimulator according to the invention. The ventricular signal picked up by the lead 5 with its electrode 7 in [figure] Figure 1 is supplied to a highpass filter 20. An amplifier 22 and an A/D converter 24 are provided for amplifying and A/D converting respectively the filtered signal. [The block 26 comprises a] A digital signal processor [for calculating] 26 calculates the average amplitudes of the measured ventricular signals and [comparing] compares them with suitably selected limit values as described above for detecting an incipient fusion.

Figure 3 is a flow [diagram] chart illustrating the function of the embodiment illustrated in [figures] Figures 1 and 2 of the heart stimulator according to the invention for [securing a] achieving 100% paced ventricular capture while optimizing the AV-interval with respect to [haemodynamic] hemodynamic conditions. [At block] In step 40 an AV interval is selected which is optimal with respect to the ventricular filling of the patient in question. This AV interval is programmed by a doctor. The pulse generator 2 starts the HOCM therapy mode with a short AV-interval, [block] step 42.

The evoked response signal average amplitude during each heart beat is monitored by the evoked response detector 4, and the AV interval is prolonged if it is shorter than the programmed AV interval, [block] step 44.

It is checked that the evoked response average amplitude has a sufficiently high, substantially constant absolute value, [at block] in step 46. If [yes] so, the AV interval is prolonged while monitoring the evoked response

amplitude according to [the] step [of block] 44. If [no] not, the AV interval is shortened with e.g. 5 msec while monitoring the evoked response amplitude, at [block] step 48.

It is then checked whether the average value formed from sampled values of the evoked response signal as described above maintains a sufficiently high and constant absolute value according to the predetermined requirements, [at block] in step 50. If [yes] so, the procedure reverts to [block] step 44, viz. the AV-interval is once again prolonged, provided that it is shorter than the programmed AV-interval, while monitoring the evoked response amplitude, and the procedure is continued to [block] step 46 as described above. If [no] not, the procedure reverts to [block] step 48, viz, the AV-interval is further shortened with 5 msec while monitoring the evoked response amplitude.

Thus the heart stimulator according to the invention is operating at an AV-interval which is as close as possible to the optimal AV-interval programmed by a doctor while securing all the time that occurrence of fusion is avoided. [Thus, in] In this way a continuous suboptimization is obtained of the programmed optimal AV-interval set by the doctor. If the evoked response average amplitude does not satisfy predetermined criteria with respect to the absolute averaged value of the amplitude and possibly the variability of the amplitude, the AV-interval is automatically shortened [till] until these criteria are again satisfied.

Figure 4 is a block diagram of the [principal layout] basic components of a second embodiment of the heart stimulator according to the invention.

This embodiment [comprises] has, in addition to the elements of the embodiment shown in [figure] Figure 1, a respiration signal determining [means] unit 28, which is supplied with the average signal values generated by the averaging [means] unit 16. The respiration signal determining [means] unit 28 generates a respiration signal, representing the respiration rate of the patient, from a predetermined number of evoked response average values. The respiration signal is supplied to the AV-interval determining [means] unit for use in the control of the pulse generator 2. The use of the respiration rate to control the operation of a pacemaker, is well known to the person skilled in the art, cf. e.g. [US-A-] United States Patent No. 4,702,253, and is therefore not described herein.

Although modifications and changes may be suggested by those skilled in the art, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications as reasonably and properly come within the scope of their contribution to the art.

3/prts

HEART STIMULATOR

Technical Field

The present invention relates to a heart stimulator according to the preamble of claim 1.

Background Art

For certain conditions such as hypertrophic obstructive cardiomyopathy (HOCM) the patient's condition may improve if he or she is paced to 100% in the ventricle. In a state of HOCM the left ventricular wall is asymmetrically thickened. The interventricular septum thickness significantly exceeds that of the opposing posterolateral wall. A pressure gradient exists across the left ventricular outflow tract and during ventricular contraction, a progressive degree of outflow tract obstruction results. The conventional site of ventricular pacing is within the right ventricular apex and pacing, prior to intrinsic R-wave excitation, from this site can favourably alter the degree of obstruction. This has been clinically verified.

100% pacing in the ventricle requires understanding of a phenomenon referred to as fusion. Fusion means that the natural conduction time, which is the time interval between an atrial activity (a sensed P-wave or a delivered A-pulse) and the subsequent natural ventricular activity (R-wave), is the same as the time (AV-interval) between an atrial activity (again, a sensed P-wave or a delivered A-pulse) and the delivery of a ventricular stimulation pulse (V-pulse). Fusion is thus a condition where the V-pulse is delivered at the same time as the R-wave occurs. Thus, fusion means that the V-pulse occurs when the heart tissue is not capable of responding, i.e. it is refractory, a tissue refractory period starting at the depolarization event (R-wave) and remaining until repolarization (T-wave) occurs. Although not necessarily harmful to the heart, fusion causes loss of energy in the V-pulse, and should therefore be avoided to save pacemaker battery energy. For the purposes of this application, both the time interval between a P-wave or an A-

pulse, and a V-pulse will be referred to as the AV-interval.

To obtain 100% pacing beats with no fusion very short AV delays have been used. Such very short AV intervals are, however, non-physiologic and therefore it is highly desirable to prolong the AV interval while maintaining a continuous monitoring of fusion, such that the AV interval would be shortened automatically if fusion beats appear. Several attempts have been made to solve this problem.

Thus, US-A-5,534,016 and 5,713,930 describe techniques for optimizing the AV interval for therapeutic purposes for patients having HOCM. In the system according to US-A-5,534,016 the T-wave detection is monitored to detect when the AV interval is lengthened to the point of evoking a fusion beat, and in the system disclosed in US-A-5,713,930 the relationship between AV intervals and QT intervals (= the time interval between a delivered ventricular stimulus and resulting T-wave) is monitored and therefrom it is determined when AV intervals correspond to full capture and when AV intervals correspond to fusion.

Further, in US-A-5,507,782 a dual chamber pacemaker is described in which the longest AV interval providing for complete ventricular capture is determined from the wave form of the ventricular depolarization R-wave following a ventricular pacing pulse for the purpose of treating patients suffering from HOCM. In this document the problems related to fusion beats and the transition region between complete pacing and fusion are not at all dealt with.

Another way of solving the problem of fusion and providing a 100% pacing of the ventricle is by AV node ablation. AV node ablation is, however, an intervention associated with extra costs and the conduction pathway from the atria to the ventricles is then destroyed for all time so the patient will be completely depending on a pacemaker in the future with higher clinical risks in the event of a pacemaker failure.

The purpose of the present invention is to provide a new heart stimulator suitable for treating HOCM patients by

accomplishing 100% paced ventricular capture, which stimulator comprises a new type of evoked response detector suitable for detecting incipient fusion in a simple and reliable way.

Summary of the invention

This purpose is obtained by a heart stimulator of the type defined in the introductory portion of this description having the characterizing features of claim 1.

In the following the expression "sensed atrial signals" denotes sensed spontaneous atrial events (P-waves) as well as stimulated atrial events (A-pulses). The interval between a sensed spontaneous atrial event and the ventricular V-pulse is denoted by PV interval, and the interval between a stimulated atrial event and the ventricular V-pulse is denoted by AV interval. The PV interval is generally shorter than the AV interval. As noted above, however, for the purpose of this patent application the PV-interval as well as the AV-interval will be referred to as the AV-interval hereinafter.

Thus, in the stimulator according to the present invention the AV-interval is continuously monitored and automatically shortened if incipient fusion is detected. Thus an incipient fusion is detected by an evoked response detector from measured ventricular signals picked up by an ventricular electrode and containing the evoked response signal, and the used AV-interval will be adjusted accordingly to be as long as possible while avoiding the occurrence of fusion beats. From a haemodynamic point of view, e.g. ventricular filling and cardiac output, such a stimulator operation will give optimum results. Thus the stimulator according to the invention will operate with an AV-interval that is optimized with respect to haemodynamic conditions.

According to an advantageous embodiment of the heart stimulator according to the invention, the controlling means are adapted to modulate the AV-interval with a predetermined amount, and said comparison means is adapted to then compare the variation of said average amplitude values obtained

during said time window with a predetermined limit. A large variability is then a clear indication of incipient fusion.

According to another advantageous embodiment, said controlling means are adapted to regularly prolong the AV-interval with a predetermined amount and said comparison means is adapted to then compare said average amplitude values obtained during said time window of cardiac cycles with said predetermined limit value and/or compare the variation of said average amplitude values obtained during said time window with a predetermined limit. In this way, incipient fusion can be detected at a very early stage and by utilizing both an amplitude criterion and a variability criterion improved reliability is obtained.

According to still another advantageous embodiment of the heart stimulator according to the invention the evoked response detector is adapted to determine the DC level of the measured ventricular signal and subtract this DC level from each sample before the average value is formed. It is important to subtract the DC level from the measured signal picked up by the electrode to get a corrected signal for subsequent analysis.

According to yet another advantageous embodiment of the heart stimulator according to the invention a respiration signal determining means is provided for determining a respiration signal representing the respiration rate of the patient, from a predetermined number of said average values.

Brief Description of the Drawings

To explain the invention more in detail, selected embodiments of the heart stimulator according to the invention will now be described with reference to the drawings, on which figure 1 is a block diagram of the principal layout of the heart stimulator according to the invention,
figure 2 is a block diagram of the evoked response detector of the heart stimulator according to the invention,
figure 3 is a flow diagram illustrating the function of the embodiment of figures 1 and 2, and

figure 4 is a block diagram of the principal layout of a second embodiment of the heart stimulator according to the invention.

Description of Preferred Embodiments

It is previously known to distinguish between completely stimulated captures, fusion beats and losses of capture from analysis of average amplitude values of recorded ventricular signals during a predetermined time window after a pacemaker stimulation, see Åsa Uhrenius et al., "Evaluation of new Algorithms for Autocapture with Unipolar Leads", CARDIOSTIM 98, Nice, June 1998.

Figure 1 shows a block diagram of the principal layout of the heart stimulator according to the invention. The stimulator comprises a pulse generator 2 which through leads 5,6 and associated atrial and ventricular electrodes 7,9 are connected to the heart 8 of a patient. The pulse generator 2 is devised to produce stimulation pulses of varying amplitudes which through the leads 5,6 with their electrodes 7,9 are transferred to the heart 8. An evoked response detector 4 of the above mentioned type is connected to the ventricular lead 5. An atrial detector comprising atrial filtering and measuring means 17 is connected to the lead 6 for measuring amplitudes of signals picked up by the atrial electrode 9. Determining means 13 are connected to the evoked response detector 4 and to said atrial filtering and measuring means 17 for determining an incipient fusion AV-interval, i.e. the AV-interval at which incipient fusion was detected, from said measured atrial signals and detected incipient fusion beats. Controlling means 15 are connected to the determining means 13 and to the pulse generator 2 for controlling the pulse generator 2 to deliver stimulation pulses at a controlled AV interval which is shorter than said incipient fusion AV-interval.

The atrial filter and measurement means 17 and the evoked response detector 4 are disconnected by switches 19 and 11 from their respective leads 5,6 during stimulation.

The evoked response detector 4 comprises filter and measuring means 10. The filtered ventricular signals picked up by the ventricular electrode 7 are supplied to a storage means 21, an averaging means 16 and to comparison means 12 for detecting incipient fusion by comparing the average amplitude obtained during a predetermined time window of the cardiac cycle from the averaging means 16 with suitably selected limit values. As appears from the above mentioned publication by Åsa Uhrenius et al. completely stimulated captures result in a comparatively large constant average amplitude whereas an incipient fusion results in a decrease of the absolute value of this average amplitude.

As an alternative, the averaging means can be adapted to form a running average value of the measured ventricular signals during said predetermined time window from a predetermined number of the latest cardiac cycles and the comparison means can be adapted to receive said running average value and compare the average value obtained during said time window of each cardiac cycle with said running average value from immediately preceding cardiac cycles.

The above mentioned limit values of the comparison means 12 can be selected such that e.g. a 10% decrease of the measured average amplitude compared to the average amplitude in a situation of completely stimulated capture is indicated as an incipient fusion. Thus, a decrease of the absolute value of the average amplitude from e.g. 26mV to e.g. 23,5mV can be interpreted as incipient fusion. In this case, a running average value as described above of e.g. the ten last cardiac cycles, is suitably used as limit value in the comparison means 12 for obtaining an acceptable signal-to-noise ratio.

Timing means 14 are provided for determining said evoked response time window during which the ventricular signal is measured and stored. This evoked response window normally extends from 15 to 55 msec after stimulation.

Thus, after a blanking time of about 15 msec the measured evoked ventricular signal is sampled and digitized

during this evoked response time window and the average value of these samples is formed. This procedure is performed in the averaging means 16, which thus supplies to the comparison means 12 an average amplitude value obtained during said time window for each heart beat. A suitable sampling frequency can be e.g. 512 Hz, which results in about 20 samples per beat.

As also appears from the publication by Åsa Uhrenius et al., the variation in the average amplitude from different cardiac cycles is comparatively small in a situation of completely stimulated capture, whereas this variation increases in a fusion situation. Thus, as an alternative embodiment, the comparison means 12 can be adapted to compare the variability of average amplitude values obtained from different cardiac cycles with a predetermined variability limit to detect an incipient fusion.

The variability criterion for indicating incipient fusion should normally be more strict than the above discussed amplitude criterion. Thus, a variability increase in the average amplitude values of e.g. 25% compared to the variability at completely stimulated capture can be used as variability criterion in the comparison means 12 for indicating incipient fusion. An increase of the peak to peak variability in the average amplitude values from different cardiac cycles from e.g. 2,5mV to e.g. 3,0mV can be interpreted as incipient fusion. Also is this case a running average value from e.g. the ten latest cardiac cycles should preferably be used.

As a further improvement of this embodiment, the controlling means 15 can be adapted to carefully modulate the AV-interval with e.g. ±5 msec or ±10 msec. A large variability appearing in the average amplitudes is then a reliable indication of fusion.

As still another alternative, the controlling means 15 can be adapted to prolong at regular intervals the AV-interval with a predetermined amount, e.g. 10 msec, and the average amplitude or variability criteria described above are checked. If the average amplitude or variability criteria

then, for this prolonged AV-interval, indicate fusion or incipient fusion, the AV-interval is shortened by 20 msec. If no changes in average amplitude or variability are noted, the AV-interval is the correct one. This would mean that the heart stimulator chooses an AV-interval which is approximately 20 msec shorter than the AV-interval at which incipient fusion is detected. In this way, a kind of check is performed to determine if the heart stimulator operates close to fusion, and in this way incipient fusion can be detected at a very early stage.

In the heart stimulator acocording to the invention it is also possible to utilize both above described amplitude and variability criteria for determining an incipient fusion which normally further improves the detection reliability.

To obtain a reliable result it is also desirable to eliminate any DC level in the measured ventricular signal. This can be performed by sampling the measured ventricular signal before the emission of a stimulation pulse and forming an average value of these samples during a cardiac cycle. This average value represents the DC level and is subtracted from each sample of the subsequent measured ventricular signal.

Figure 2 shows in greater detail one embodiment of the evoked response detector of the heart stimulator according to the invention. The ventricular signal picked up by the lead 5 with its electrode 7 in figure 1 is supplied to a highpass filter 20. An amplifier 22 and an A/D converter 24 are provided for amplifying and A/D converting respectively the filtered signal. The block 26 comprises a digital signal processor for calculating the average amplitudes of the measured ventricular signals and comparing them with suitably selected limit values as described above for detecting an incipient fusion.

Figure 3 is a flow diagram illustrating the function of the embodiment illustrated in figures 1 and 2 of the heart stimulator according to the invention for securing a 100% paced ventricular capture while optimizing the -AV-interval

with respect to haemodynamic conditions. At block 40 an AV interval is selected which is optimal with respect to the ventricular filling of the patient in question. This AV interval is programmed by a doctor. The pulse generator 2 starts the HOCM therapy mode with a short AV-interval, block 42.

The evoked response signal average amplitude during each heart beat is monitored by the evoked response detector 4, and the AV interval is prolonged if it is shorter than the programmed AV interval, block 44.

It is checked that the evoked response average amplitude has a sufficiently high, substantially constant absolute value, at block 46. If yes, the AV interval is prolonged while monitoring the evoked response amplitude according to the step of block 44. If no, the AV interval is shortened with e.g. 5 msec while monitoring the evoked response amplitude, at block 48.

It is then checked whether the average value formed from sampled values of the evoked response signal as described above maintains a sufficiently high and constant absolute value according to the predetermined requirements, at block 50. If yes, the procedure reverts to block 44, viz. the AV interval is once again prolonged, provided that it is shorter than the programmed AV interval, while monitoring the evoked response amplitude, and the procedure is continued to block 46 as described above. If no, the procedure reverts to block 48, viz. the AV interval is further shortened with 5 msec while monitoring the evoked response amplitude.

Thus the heart stimulator according to the invention is operating at an AV-interval which is as close as possible to the optimal AV-interval programmed by a doctor while securing all the time that occurrence of fusion is avoided. Thus, in this way a continuous suboptimization is obtained of the programmed optimal AV-interval set by the doctor. If the evoked response average amplitude does not satisfy predetermined criteria with respect to the absolute averaged value of the amplitude and possibly the variability of the

amplitude, the AV interval is automatically shortened till these criteria are again satisfied.

Figure 4 is a block diagram of the principal layout of a second embodiment of the heart stimulator according to the invention.

This embodiment comprises, in addition to the elements of the embodiment shown in figure 1, a respiration signal determining means 28, which is supplied with the average signal values generated by the averaging means 16. The respiration signal determining means 28 generates a respiration signal, representing the respiration rate of the patient, from a predetermined number of evoked response average values. The respiration signal is supplied to the AV-interval determining means for use in the control of the pulse generator 2. The use of the respiration rate to control the operation of a pacemaker, is well known to the person skilled in the art, cf. e.g. US-A-4,702,253, and is therefore not described herein.

Claims

1. A heart stimulator comprising atrial and ventricular stimulating means (2) for producing stimulation pulses for delivery to a patient's heart (8), atrial sensing means (6,9,17) for sensing atrial signals, an evoked response detector (4) for detecting evoked response signals, determining means (13) for determining an incipient fusion AV-interval from said sensed atrial signals and detected evoked response signals, and controlling means (15) for controlling said ventricular stimulating means to deliver stimulation pulses at a controlled AV-interval which is shorter than said incipient fusion AV-interval, characterized in that said evoked response detector (4) includes an averaging means (16) provided to form an average amplitude value of said evoked response signal during a predetermined time window of each cardiac cycle, and a comparison means (12) arranged to compare said average value for each cardiac cycle with predetermined limit criteria and supply the result of said comparison to said determining means (13) for determining whether a detected evoked response signal results from an incipient fusion beat or a completely stimulated capture.

2. The heart stimulator according to claim 1, characterized in that said comparison means (12) is adapted to compare said average value with a predetermined limit value.

3. The heart stimulator according to claim 1, characterized in that said averaging means (16) is adapted to form a running average value of said evoked response signals during said predetermined time window from a predetermined number of the latest cardiac cycles which running average value is used in determining said limit criteria.

4. The heart stimulator according to claim 3, characterized in that said comparison means (12) is adapted to receive said running average value and compare the average value obtained during said time window of each cardiac cycle

with said running average value from immediately preceding cardiac cycles.

5. The heart stimulator according to claim 3, characterized in that said comparison means (12) is adapted to compare the variation of said average values obtained during said time window of the cardiac cycles with a predetermined variability limit.

6. The heart stimulator according to any of the preceding claims, characterized in that said controlling means (15) are adapted to modulate the AV-interval with a predetermined amount, and in that said comparison means (12) is adapted to then compare the variation of said average values obtained during said time window of the cardiac cycles with a predetermined variability limit.

7. The heart stimulator according to any of the claims 1 - 4, characterized in that said controlling means (15) are adapted to regularly prolong the AV-interval with a predetermined amount, and in that said comparison means (12) is adapted to then compare the said average amplitude values obtained during said time window of the cardiac cycles with said predetermined limit value and/or predetermined variability limit.

8. The heart stimulator according to claims 5 or 6, characterized in that said controlling means (15) are adapted to modulate the AV-interval with a predetermined amount, and in that said comparison means (12) is adapted to then compare the variation of said average values obtained during said time window of the cardiac cycles with said predetermined variability limit.

9. The heart stimulator according to any of the preceding claims, characterized in that said evoked response detector (4) is adapted to sample and digitize said evoked response signals for each heart beat in a predetermined evoked response time window starting a predetermined time after the delivery of a stimulation pulse to the ventricle to form the average value of said amplitude samples.

10. The heart stimulator according to claim 9, characterized in that sampling frequency and length of said evoked response time window are chosen such that a number of samples of the order of 20 is obtained within each evoked response time window.

11. The heart stimulator according to claim 9 or 10, characterized in that said evoked response detector (4) is adapted to determine the DC level of the measured ventricular signals and subtract this DC level from each sample before the average value is formed.

12. The heart stimulator according to any of the preceding claims, characterized in that a respiration signal determining means (28) is provided for determining a respiration signal, representing the respiration rate of the patient, from a predetermined number of said average values.

13. The heart stimulator according to claim 12, characterized in that said respiration signal determining means (28) is adapted to determine said respiration signal from variations of the amplitudes of said predetermined number of average values.

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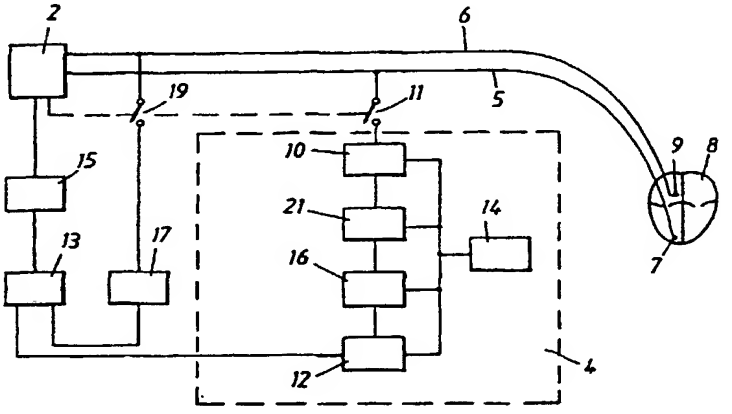
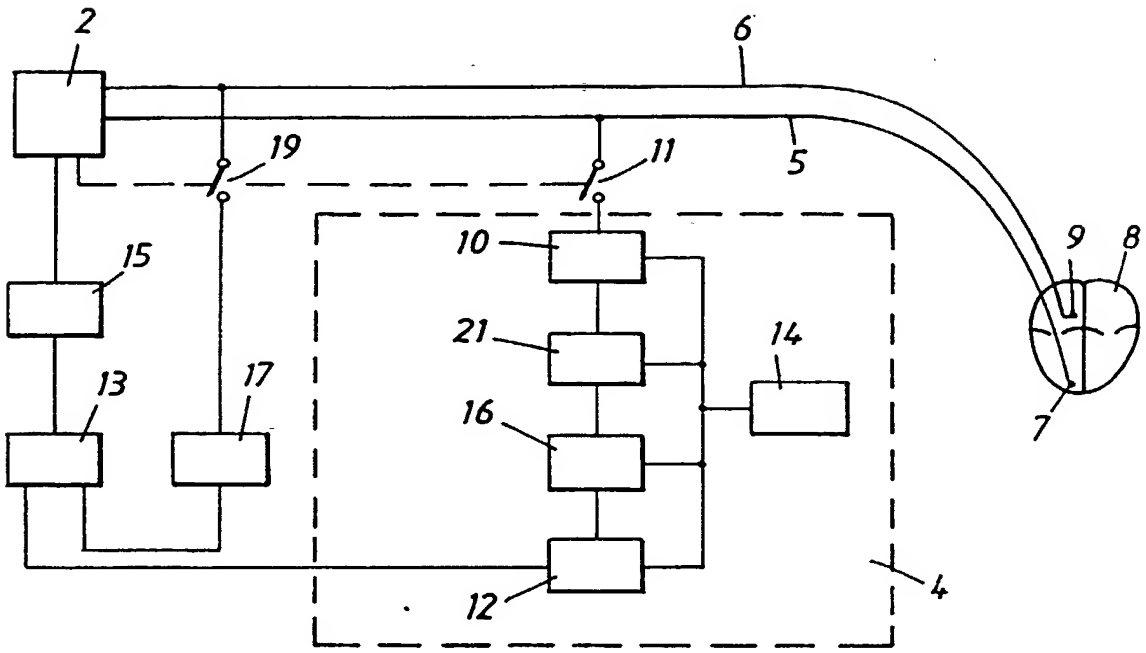


(57) Abstract: A heart stimulator comprises atrial and ventricular stimulating means including a pulse generator (2) for producing stimulation pulses for delivery to the ventricle of a patient's heart (8). Atrial sensing means (7, 9, 17) are provided for sensing atrial signals and an evoked response detector (4) is provided for detecting the occurence of incipient fusion beats from measured ventricular signals. Determining means (13) are provided for determining an incipient fusion AV-interval from the sensed atrial signals and detected fusion beats, and controlling means (15) are provided for controlling said pulse generator to deliver stimulation pulses at a controlled AV-interval which is shorter than the incipient fusion AV-interval. The evoked response detector (4) includes an averaging means (16) provided to form an average amplitude value of the measured ventricular signals during a predetermined time window of each cardiac cycle, and a comparison means (12) arranged to compare said average value for each cardiac cycle with predetermined limit criteria and supply the result of said comparison to said determining means (13) for determining whether a measured ventricular signal results from an incipient fusion beat or a completely stimulated capture.

WO 01/17608 A1

Fig. 1


2
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4

Fig. 2

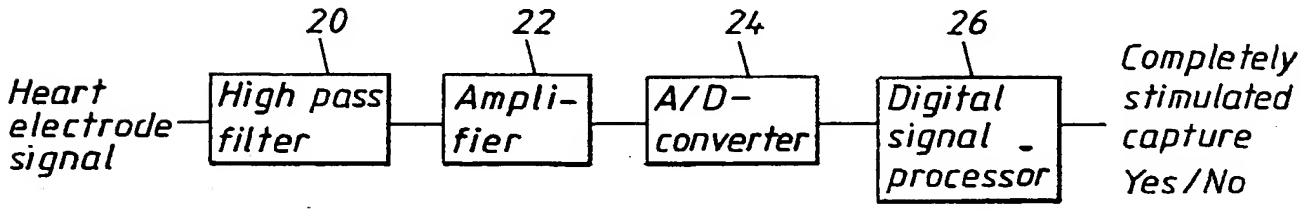

20
22
24
26
Heart electrode signal
High pass filter
Ampli-fier
A/D-converter
Digital signal processor
Completely stimulated capture Yes/No

Fig. 3

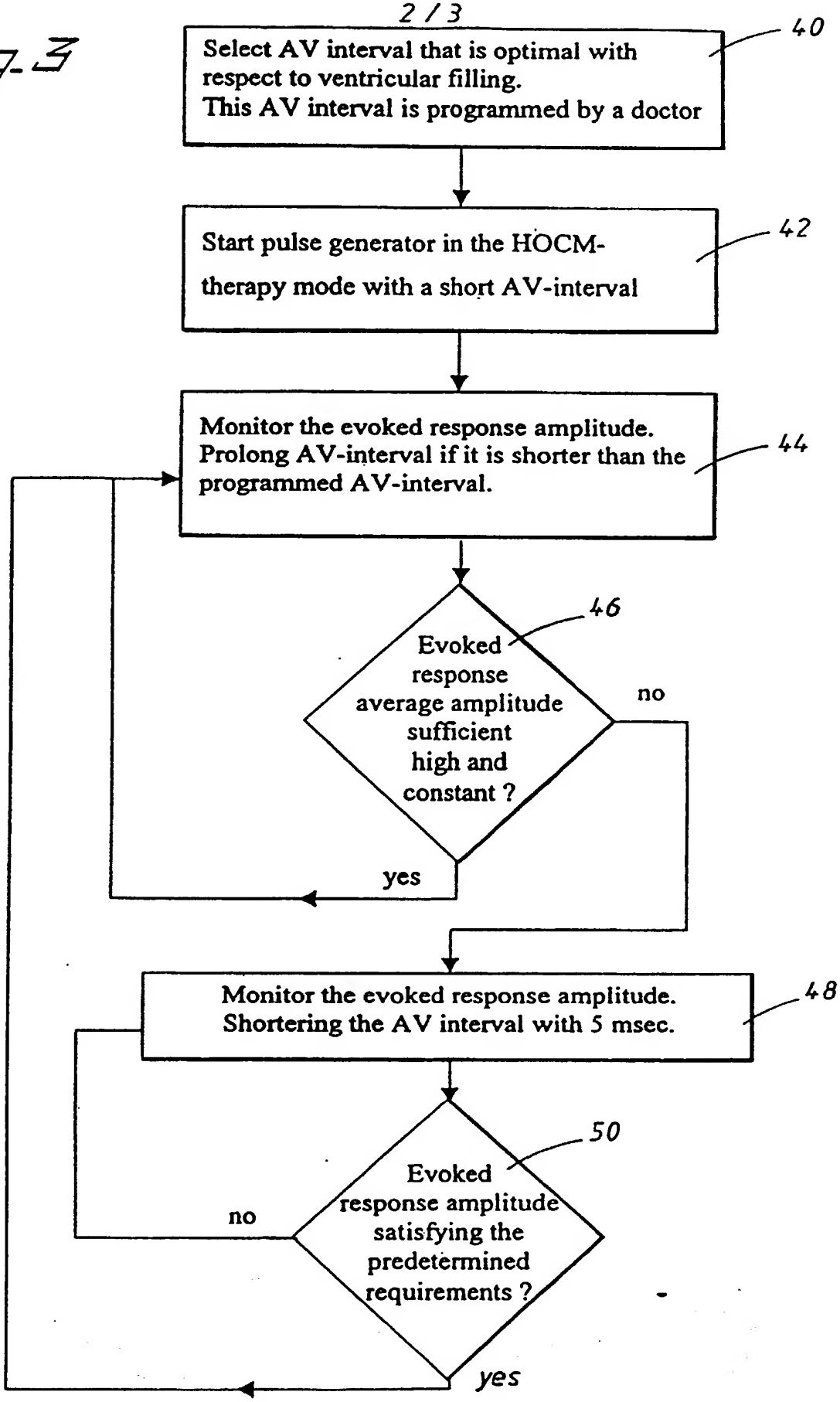
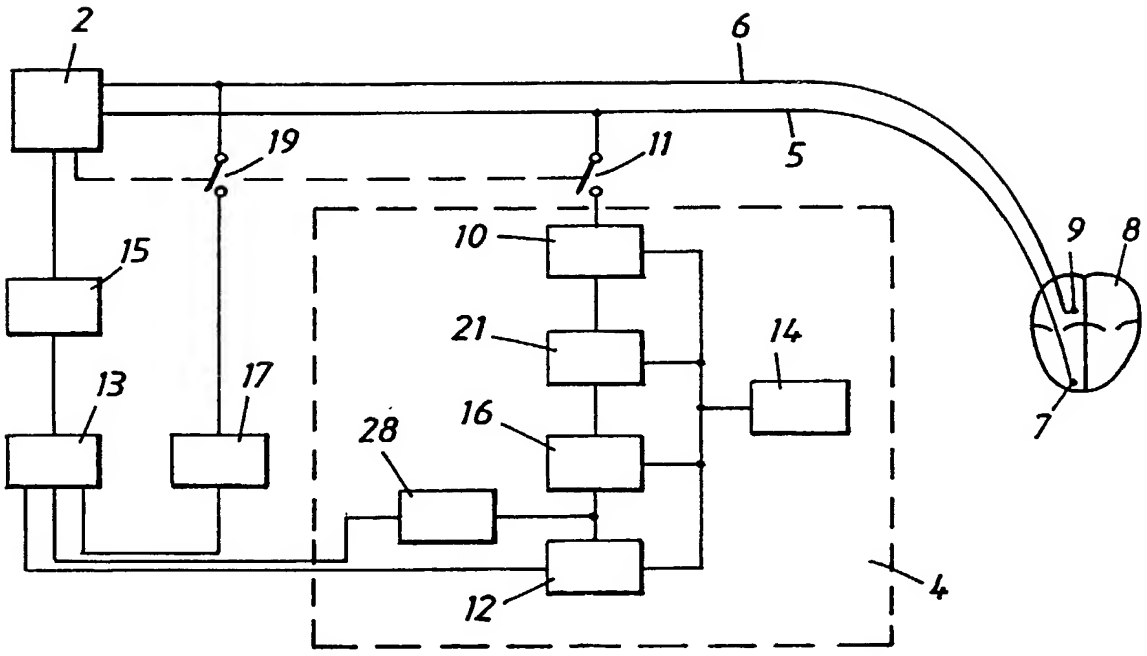

Select AV interval that is optimal with respect to ventricular filling. This AV interval is programmed by a doctor
40
Start pulse generator in the HOCM-therapy mode with a short AV-interval
42
Monitor the evoked response amplitude. Prolong AV-interval if it is shorter than the programmed AV-interval.
44
Evoked response average amplitude sufficient high and constant ?
46
no
yes
Monitor the evoked response amplitude. Shortering the AV interval with 5 msec.
48
Evoked response amplitude satisfying the predetermined requirements ?
50
no
yes

Fig. 4



COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NUMBER P02,0085

As a below named inventor, I hereby declare that:

My residence, post office **address** and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

"DUAL CHAMBER HEART STIMULATOR WITH EVOKED RESPONSE DETECTOR" (AS AMENDED)

the specification of which (check only one item below):

□ is attached hereto.

■ was filed as United States application
Serial No. **10,070,470** ✓

on **March 7, 2002** ✓,

and was amended

on **March 7, 2002** ✓ (if applicable).

□ was filed as PCT international application

Number _____

on _____,

and was amended under PCT Article 19

on _____ (if applicable).

I hereby state that I have reviewed and understand the contest of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

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COUNTRY (if PCT indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Sweden ✓	**9903205-4** ✓	**9 September 1999** ✓	■ YES □ NO
			□ YES □ NO
			□ YES □ NO
			□ YES □ NO
			□ YES □ NO

Combined Declaration For Patent Application and Power of Attorney (Continued)
(Includes Reference to PCT International Applications)

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P02,0085

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject mater of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, Untied States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

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U.S. APPLICATIONS		STATUS (Check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED
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PCT APPLICATION NO	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)		

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	POST OFFICE ADDRESS	POST OFFICE ADDRESS:	CITY:	STATE & ZIP CODE/COUNTRY:

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
DATE JUNE 16, 2002	DATE June 20, 2002	DATE